AGRICULTURAL ENGINEERING

Published by the AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS, St. Joseph, Michigan

Publication Office, Benton Harbor, Michigan. Editorial and Advertising Departments, St. Joseph, Michigan

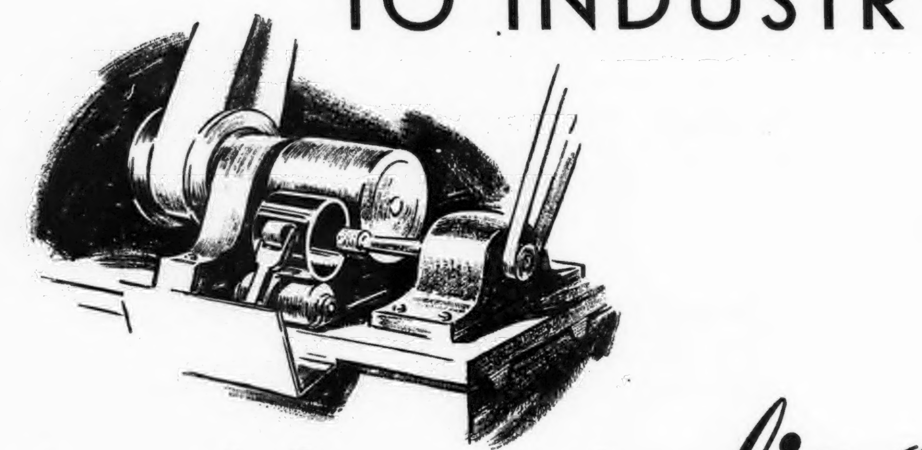
ARTHUR HUNTINGTON, PRESIDENT RAYMOND OLNEY, SECRETARY-TREASURER

Volume 14 DECEMBER 1933 Number 12

CONTENTS

Subscription price to non-members of the Society, $3.00 a year, 30 cents a copy; to members of the Society, $2.00 a year. Postage to countries to which second-class rates do not apply, $1.00 additional. Entered as second-class matter, October 28, 1933, at the post office at Benton Harbor, Michigan, under the Act of August 24, 1912. Additional entry at St. Joseph, Michigan. Acceptance for mailing at the special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized August 11, 1921. The title AGRICULTURAL ENGINEERING is registered in the U. S. Patent Office.

WE HAND A NEW TOOL TO INDUSTRY



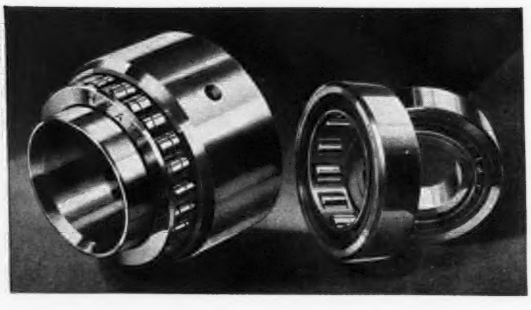
Chuckless grinding

The problem of making races for bearings with wall variations held to an irreducible minimum, that is, with bores and outside diameters truly concentric, has intrigued engineers for years.

Hyatt determined to solve the problem and now with considerable pride and satisfaction we announce the new process which we have originated and nurtured through persistent effort—we call it chuckless grinding.

Soon, all other industries may benefit from this Hyatt research and experimentation which has taken years of effort and which to perfect, cost thousands of dollars in our plant and elsewhere.

But, the furthering of this revolutionary development of grinding accuracy in race manufacture, is only another measure of Hyatt endeavor to find better ways to safeguard quality. We thus hope to insure the continued faith of Hyatt customers. Hyatt Roller Bearing Company, Newark, Detroit, Chicago, Pittsburgh, Oakland.



HYATT

ROLLER BEARINGS

PRODUCT OF GENERAL MOTORS

AGRICULTURAL ENGINEERING

Volume 14 DECEMBER 1933 Number 12

Producing a Potato Crop with the All-Purpose Tractor[1]

By R. U. Blasingame[2] and A. W. Clyde[3]

THIS paper is limited to the problems involved in the development and adaptation of equipment to be used with the all-purpose tractor in the growing of potatoes on a commercial scale and to the utilization of such equipment. The objective of the research work here summarized is the reduction of the cost of power, labor, and machinery in potato production through better agricultural engineering practice. Such costs as rent, insurance, taxes, seed, commercial fertilizer, manure, spray materials, hauling, and grading are not included in this paper because they have no relation to power costs of field operations.

Agronomists and pathologists have been conducting research studies over a long period and have developed basic data on seed selection, soil fertility, and spray practices for potato production which, when accurately applied on good soil and with reasonably favorable growing season, will produce more satisfactory yields.

Having in mind the well-established fact that power and labor costs represent from 40 to 60 per cent of the total cost of producing potatoes as well as certain other crops, members of the agricultural engineering department of the Pennsylvania State College began in 1929 a comprehensive research program to determine whether or not potato yields could be further increased and production costs further reduced by the use of all-purpose tractors with suitable attachments.

Early in the course of this research program, it became apparent that many changes in equipment layout would be necessary to secure due advantages and benefits from the use of the all-purpose tractor in commercial potato growing.

The following changes in this direction have thus far been made:

1. *Sprayer.* The engine was removed from the sprayer, and the spray pump was operated by the power take-off from the tractor. This took the weight of the engine from the sprayer and reduced the cost of operations. The tractor has ample power for the dual function of pulling the machine and operating the pump.

2. *Weeder.* A weeder was designed and built which attaches directly to the tractor drawbar. It can be put on or taken off by one man when the tractor is to be used for other jobs.

3. *Digger.* A power take-off potato digger was built. Its advantages are that the speed of the digger elevator can be varied to meet different conditions independent of the tractor, and that the elevator chain

[1]Paper presented at a meeting of the Power and Machinery Division of the American Society of Agricultural Engineers held at Chicago, December 1933. Publication authorized by the Director of the Pennsylvania Agricultural Experiment Station, November 21, 1933, as Technical Paper No. 619.

[2]Head, department of agricultural engineering, The Pennsylvania State College. Mem. A.S.A.E.

[3]Research engineer, department of agricultural engineering, The Pennsylvania State College. Mem. A.S.A.E.

[4]Missouri Agricultural Experiment Station Research Bulletin No. 197, Minnesota Agricultural Experiment Station Bulletin No. 280, Illinois Agricultural Experiment Station unpublished data on tractor costs. Iowa Engineering Bulletin No. 92, and South Dakota Agricultural Experiment Station Circular No. 6.

(AUTHORS' ACKNOWLEDGMENTS: The authors desire to express their appreciation for the cooperation of the following persons and commercial interest: Dr. C. R. Noll, College farm superintendent, who supplied the land, seed, spray materials, labor, and agronomic advice; Dr. E. L. Nixon, for advice on pathology; Roy B. Johnson, tractor operator; International Harvester Company, for tractor, plow, and cultivator; Babcock Mfg. Co., for weeder; Killefer Mfg. Corp., for cover-crop disk and chisel; Massey-Harris Co., for the field cultivator; Deere & Co., for power-take-off digger; John Bean Mfg. Co., for power-take-off sprayers, and Fred H. Bateman, for planter.)

(Left) Planting potatoes with a two-row machine. (Right) Combination cultivator and weeder used first before the potato crop comes up


(Left) Cultivating potatoes the third time with spring-tooth cultivator. (Right) Eight-row, power-take-off sprayer — three nozzles to the row — operating at 400-lb pressure

can be run with the tractor standing still in case the digger becomes too heavily loaded or clogged.

4. *Cultivator.* Spring-tooth cultivators were adapted which have reduced breakage where tight stones occur in the soil.

5. *Vine Lifter.* An improvement was made in the vine lifter by attaching small rods at the rear which lessen vine damage by the sprayer wheels.

6. *Tractor Plow Spring Hitch.* In parts of Pennsylvania tight stones are encountered; indeed, this condition exists in many sections of the country. This has been a serious drawback to tractor plowing in the past causing (1) loss of time and (2) breakage of plows. To overcome this difficulty a very successful spring overload release plow hitch has been developed. This device throws out the tractor clutch through a large spring which also protects the plow against the shock of stopping the tractor.

7. *Harvesting.* It was found that one-third of the labor in potato crop production was required to pick up the potatoes by hand at harvest. In order to reduce the cost of this laborious job a potato harvester has been designed and built.

The following equipment was found well adapted to tractor operation without change: Plow, spring-tooth harrow, cover-crop disk, chisel, field cultivator, planter, and digger (with a front truck to regulate the depth).

In order to obtain accurate information, the potato acreage is determined; all fertilizer is weighed; fuel, oil, and grease for each operation are weighed and measured; a service recorder equipped with a clock mechanism is attached to the tractor which makes a chart record of the time the tractor is idle or in operation each day.

Seedbed Preparation. On the College farm potatoes follow clover and timothy. Potatoes need a deep, loose seedbed with considerable organic matter well mixed in. The best procedure in our rather heavy soil (Hagerstown silt loam) seems to be plowing 7 to 8 in deep in the winter or early spring. Spring plowing is usually followed by spring-tooth harrowing to save moisture. Later the field is disked with a cover-crop disk to mix the organic matter with the soil. If rains compact the soil after disking, it is advisable to loosen it just before planting. For this purpose we tried both chiseling a little deeper than the plow depth and cultivating about 5 in deep with a spring-tooth field cultivator. On this limestone soil there seems to be nothing gained in yield by preparing deeper than plow depth, and since chiseling or subsoiling is considerably more expensive than field cultivating, it does not seem justified. There are, however, other soil conditions where chiseling could probably be advantageously substituted for plowing, especially after previous crop of soybeans instead of clover.

Manure and Fertilizer. About ten tons of barnyard manure per acre was applied in the early fall. About 850 lb of 4-10-9 fertilizer was applied slightly below and on each side of the seed when the crop was planted.

Planting and Seed. The field was seeded with a two-row, automatic picker planter having a fertilizer attachment, this machine being calibrated to sow the correct amount of fertilizer and the picks being adjusted to the size of seed before putting it into the field. The rows were 34 in apart and the seed pieces were spaced 10 in in the row. This machine will place the tubers at an optimum depth of 3 in below the level and covers them shallow. Shallow covering is declared by some pathologists to aid in the control of Phizoctonia and to hasten germination and growth of the plants. If care is exercised in having the seed uniform in size, weighing about 1½ oz, the planter will do an excellent job of planting. Coil springs and wooden breakpins have been added to the furrow opener (or runner) to minimize breakage when tight stones are encountered.

Two kinds of seed are usually planted: (1) New certified or disease-free seed, and (2) second year seed from the previous crop. After the second year, diseases appear to become prevalent, which is the reason for new foundation seed stock each year. As a rule, about 24 bu of seed is required per acre.

Foliage Protection—Spraying. Bordeaux mixture is used for foliage protection from insects and disease and to counteract damage from heat and drought. Bordeaux is made with 8 lb of copper sulphate, 8 lb of quick lime, and 100 gal of water. Fifty pounds of copper sulphate is dissolved in a 50-gal wooden barrel. Fifty pounds of lime is slaked in a 50-gal steel drum. In slaking quick lime the quantity of water is accurately controlled, because too much water "drowns" the lime and too little "burns" it. Both result in sediment which makes an inefficient Bordeaux, causing nozzle clogging, pump and valve trouble, as well as less effective foliage protection. Wooden barrels and wooden stirring paddles are avoided for lime slaking because they disintegrate, yielding a pulp that causes serious nozzle clogging. A Bordeaux mixing plant is used to facilitate making a chemically accurate spray solution and to give effective handling of the water and stock solutions.

Spraying is begun as soon as the rows can be followed and is continued at seven to ten-day intervals for three sprays. This is the "foundation series." These sprays preclude the infection of the blights and repel insects.

The second spray series controls insects and coun-

Table I. Typical Power and Labor with Tractor for One Acre of Potatoes
(Most of this data is based on 5 years' results on about 15 acres per year)

Operation	Machine	Man-hours per acre*	Tractor-hours per acre	Fuel, gal per acre**	Oil, gal	Grease, lb
Plow	2-bottom, 14-in	2.15	1.79	3.00		
Spring-tooth harrow	32 teeth, 12½ ft	0.31	0.27	0.57	See total	See total
Disk harrow	Covercrop, 5 ft	0.73	0.64	1.13		
Field cultivate	Spring-tooth, 7½ ft	0.50	0.42	0.75		
Plant and fertilize	2-row, 68 in	3.20†	1.20	1.20		
Cultivate or cultivate and weed 4 times	2-row, 68 in	2.60	2.15	3.00		
Weed twice	6-row, 204 in	0.54	0.33	0.50		
Spray 11 times	8-row, 272 in (power take-off	3.52††	2.50	3.60		
Dig	1-row (power take-off)	2.60	2.20	2.58		
Total for above operations		16.15	11.50	16.33	0.8	0.6

*Includes time going to and from field, servicing tractor, making field adjustments and repairs, etc.
**About 2/3 kerosene and 1/3 gasoline. Mixtures were sometimes used.
†Two men planting and fertilizing.
††About 0.7 hours additional time needed per acre to prepare spray material.

teracts intense heat. In this series, 2 lb of extra lime per each 100 gal of Bordeaux are used. These sprays are applied at seven to eight-day intervals depending upon the temperature. The hotter the weather, the more frequent the sprays.

Blight control constitutes the third series, and again the frequency depends upon weather conditions and the prevalence of late blight. Under severe conditions five to eight-day intervals may be necessary, while ten-day intervals are the maximum under any conditions. As a rule, ten to twelve sprays are applied each season.

The all-purpose tractor power take-off is ample for spray pump requirements, the minimum of which is 2 gal per minute per row, 250 to 300 lb pressure per square inch at the nozzle, 150 gal of spray per acre and three adjustable nozzles to the row. This usually requires about one horsepower per row with present pumps.

An 8-row spray boom has been employed in this potato production program. The boom and nozzles are carefully adjusted to the size and height of the plants. In general, the nozzles are adjusted 18 to 20 in from the optimum amount of foliage to be protected. The tractor speed is regulated to apply a minimum of 150 gal of spray per acre.

Cultivation and Weeding. After the potato crop has been planted and before the plants can be seen in the row, the cultivator is run as deep as practicable. This is spoken of as "blind cultivation." Then, as soon as the rows can be seen, the field is weeded. These two operations destroy the first crops of tiny weeds before they are large enough to be troublesome and while they are easily controlled. As a rule the field is cultivated about four times during the growing season. Usually the weeder is run after each rain. In case of no rain weeding is done at intervals of about 7 to 10 days until the vines are about a foot high. It

Table II. Overhead Costs of Tractor
(600 hr use per year, 10-yr life)

Depreciation ($900 ÷ 10)	$ 90.00
Interest on average value, [900 + 90] ÷ 2 at 6%	29.70
Repairs at 8c per hr (or 5-1/3% of first cost)	48.00
Housing, taxes, and insurance	10.00
Total overhead cost per year	$177.70
Overhead charge per hour	$ 0.30

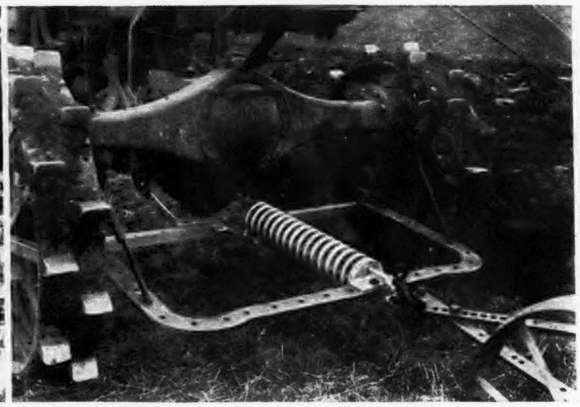
Table IV. Cost Estimate per Acre of Work with Tractor in Growing 40 Acres of Potatoes*

Power and Labor Cost per Acre		
Overhead cost of tractor, 11½ hr at 30c	$ 3.45	
Fuel, 16-1/3 gal at 12c	1.96	
Oil, 0.8 gal at 70c	.56	
Grease, 0.6 gal at 15c	.09	
Labor, 16.15 hr at 30c	4.85	
Total		$10.91
Machinery Costs Other Than Tractor per Acre		
Plow, two-bottom, 14-in	$ .43	
Spring-tooth harrow, 12½ ft	.08	
Disk, cover-crop, 5 ft	.30	
Field cultivator, 7½ ft	.21	
Planter, 2-row automatic	1.05	
Cultivator, 2-row (or parts of cultivator and weeder) four times over at 18c	.72	
Weeder, twice at 15c	.30	
Sprayer, 8-row, 11 times over at 29c	3.19	
Digger, 1-row	1.04	
Total		7.32
Total power, labor, and machinery		$18.23

*Includes digging but does not include the following items which would be about the same regardless of power used: applying manure, cutting seed, mixing spray materials, hand weeding or hoeing, picking up potatoes, and hauling fertilizer, seed, and the crop.

Table III. Annual Cost of Machinery

Machine	Acres covered once per yr	Days used per yr	Cost new	Life in years	Depreciation, per cent	Interest, insurance, housing, per cent	Repairs: Cost	Repairs: Per cent of cost new	Total yearly cost: Per cent of cost new	Total yearly cost: Amount	Cost per acre once over
Plow	70	15	$115	12	8.3	5	$15.00	13	26.3	$30 25	$0.43
Spring-tooth harrow	100	3½	52	15	6.7	5	2.00	4	15.7	8.15	0.08
Disk, cover crop	60	4½	130	15	6.7	5	2.60	2	13.7	17.80	0.30
Field cultivator	80	2-2/3	120	15	6 7	5	3.00	2½	14.2	17.00	0.21
Planter	40	6½	275	12	8.3	5	5.50	2	15.3	42 10	1 05
Cultivator and vine lifters	160	10	160	10	10.0	5	4.80	3	18.0	28.80	0.18
Weeder	80	2	95	15	6.7	5	1.00	1	12.7	12.00	0.15
Sprayer	440	14	750	10	10.0	5	15.00	2	17.0	127.50	0.29
Digger	40	10	220	10	10.0	5	8.80	4	19.0	41.80	1.04

(Left) A potato vine lifter to protect the vines from damage by the sprayer wheels. (Right) One of the two successful tractor stop-hitches used in the Pennsylvania experiments

is common practice to run the weeder in the same direction over the vines each time.

It has been the practice in some of the cultivations to substitute the two-row section of the weeder at the rear of the tractor for the rear cultivator teeth, leaving the two-row cultivator in front. This makes a combination weeder and cultivator. The authors doubt, after several years' study, that this combination is the best practice. Hereafter, it will be the practice to employ both front and rear cultivators for cultivation and then run the 6-row weeder when needed, without the cultivator. It must be remembered that the weeder destroys only very tiny weeds. Its effectiveness in weed control is best when the ground is loose. If the field is hard, cultivation is essential before weeding.

436-Bushel Yield. By this year the all-purpose tractor equipment for potato production had been perfected to the point where, with a fairly good growing season, the production was 436 bu on a measured acre. This makes this department eligible for the 400-bu club which was organized several years ago by representatives of the Pennsylvania State College and sponsored by the Pennsylvania Potato Growers' Association. Eligibility for the club is based on the production of 400 bu or more per acre on a measured acre. The production (by weight) must be certified by a responsible disinterested party.

Thus it has been established beyond a doubt that satisfactory potato yields can be had with tractor power and with a minimum expenditure of power and labor. There is no doubt that with tractor power and proper equipment, field operations can be quickly and thoroughly done at the times when they pay best. Each year potatoes have been grown on the College farms with horses as well as with tractor power. The yields on the tractor fields have been as good or better where tractor power was used, although no comparable tests have been made.

Size of Field. Comparatively small fields of about 15 acres of potatoes have been grown each year. This acreage was consistent with good research practice in view of the fact that machinery often had to be altered during the growing season. With the present equipment set-up, much larger acreages could be handled by a commercial potato grower.

For instance, with the all-purpose tractor 15 acres of potatoes can be covered once over in the following number of hours: Plowing, 32; spring-tooth harrowing, 4¾; disking, 11; field cultivating (seedbed preparation), 7½; planting, 24 (2 men); cultivating, 10; weeding, 4; spraying, 5.

Basis for Computing Costs. Tables II, III, and IV give cost estimates for the tractor field operations listed in Table I on 40 acres per year. The 40-acre basis is chosen because it is believed to be a conservative estimate of what the tractor and equipment could handle without additional power or unusually long days. One peak comes during cultivating, weeding, and spraying, and a second during digging; these are probably the limiting factors. It is assumed that the tractor and machinery for seedbed preparation will be used for other crops; therefore, its yearly cost is divided according to acreage. In Table III interest on the average investment is combined with insurance, taxes, and housing to make a total of 5 per cent of the first cost.

Estimates of life, repairs, etc., are based on our own experience and surveys, and on information from several other experiment stations[4]. The authors have tried to make all estimates conservative because experience in rather stony ground through central Pennsylvania shows that machinery has shorter life and higher repair expense per acre than in stone-free localities. The repair expense of 8c per hour for a 2-plow tractor is higher than many estimates. Lower estimates, however, are often based on rather new tractors which have not had a major over-haul. When that is made, the repair charge goes up sharply. In this connection, it may be mentioned that the tractor used in this experiment is one of the early general-purpose types and is now 8 years old.

RECOMMENDATIONS FOR FURTHER STUDY

Both the track and the wheel type tractors have proved adaptable to potato planting and digging. Rubber tires may have possibilities for improving the performance of wheel tractors. Most tractors have been built to run on kerosene for the purpose of reducing the cost of fuel and ordinarily have a compression ratio of about 4½ to 1. When users attempt to burn gasoline with an antiknock rating of 66 or more in kerosene tractors the efficiency is low.

Many owners prefer to use gasoline instead of kerosene. There is, therefore, a need for a higher compression engine which will be more efficient with gasoline. A 200-cu in, four-cylinder engine of good design can have a ratio of about 5½ to 1 for regular gasoline, or somewhat less for poor grades. It will develop considerably more power than the kerosene engine from the same amount of fuel. We believe that tractor manufacturers should give customers a choice of two or three-cylinder heads, so that the proper compression can be obtained for the fuel used. Buyers could well afford to pay any extra cost involved.

Although manufacturers have made notable improvements which have strengthened their tractor-drawn machinery, we feel that there are still a few

parts which need to be made more rugged for working our heavy, stony soil. The time lost when an outfit is idle and should be working increases production costs. A short delay on a two-row cultivator is as costly as a much longer delay with a one-row outfit. A few definite suggestions for the improvement of equipment are listed below, but no particular manufacturer is mentioned because in general all makes of machines might be improved in certain respects as follows:

1. We have used two different tractor stop-hitches during the past two years which protect the plow and digger when stones and other obstacles are encountered. One type was developed by a manufacturer and the other by ourselves. Both stop the tractor when a solid stone is hit and cushion the shock on the plow. It is hoped that something will soon be put on the market for use on our potato farms.

2. Eight and ten-row booms for sprayers need to be rugged and still flexible enough to yield when they strike a tree or fence post, and the life of steel pipe should be lengthened for use under the corrosive action of Bordeaux spray. We are replacing standard pipe with extra heavy pipe, but that merely postpones failure. Manufacturers should investigate brass pipe or some means of protecting steel pipe from corrosion.

3. Crops are damaged by sprayer and tractor wheels. The rows next to the sprayer tracks average less bushels per acre than other rows. No one seems to know whether the damage is due chiefly to packing, to root pruning, or to vine injury. While the cause is being studied it might be worth while to see the effect of rubber tires on the sprayer and tractor.

4. A potato digger must plow up the potatoes, separate them from vines, stones, dirt, and clods, and leave them visible on top of the ground so they can be easily gathered. Lack of understanding of the handling of the digger and adjustments sometimes causes considerable damage. The early potato diggers were simple in design but handled far less dirt than present diggers. Their weakness was due to the fact that they did a poor job of separating potatoes from vines and left many potatoes covered with dirt, making the job of gathering more difficult. Present diggers seem to us to handle too much dirt. We confidently expect to see manufacturers improving their potato digger equipment.

5. Nearly the entire crop of potatoes is picked by hand in a primitive, laborious, back-breaking manner. Several machines are being tried to make this work easier. We have developed one which removes the drudgery and reduces the cost of harvesting. It has been used on 15 acres for the past three years. It is hoped that the manufacturers may accelerate their research programs on this problem to such an extent that we may soon see potato harvesters on the market.

The Abrasive Effect of Lime as Used in Bordeaux Mixture[1]

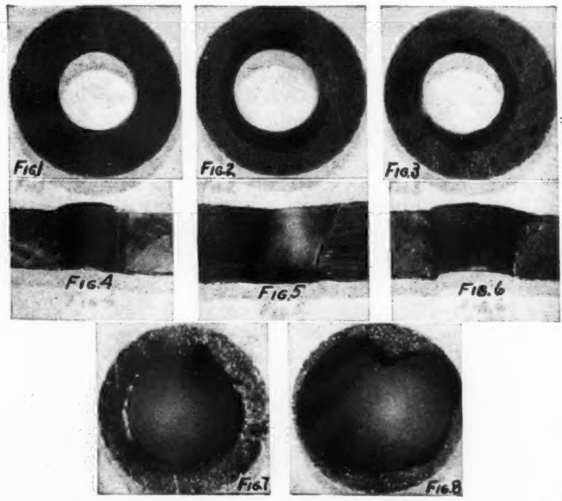
By E. L. Nixon[2]

SINCE the discovery of Bordeaux mixture much experimental work has been devoted to its perfection. Many changes in its preparation have resulted from greater knowledge of the factors determining its effectiveness. One of the earliest changes had to do with the reduction of the copper content. The lime, too, has had its share of consideration especially as concerned the amount in relation to the copper. As to form, all of the earlier formulas recommended fresh stone-lime, referred to also as lump lime. During this early period not a great deal of attention was paid to the quality of the lumps. It was more a case of using what was available. Now a hand-picked product in convenient airtight containers in which it is preserved indefinitely without deterioration is on the market. Thus with a technique acquired to slake it properly, growers can now make the most perfected Bordeaux mixture since its discovery. Experimentation has shown that the standard 4-4-50 formula is the most effective and economical.

During the period when a good quality of stone lime was difficult to procure and more difficult to pre-

[1]Paper presented at a meeting of the Power and Machinery Division of the American Society of Agricultural Engineers during the annual meeting of the Society held at Chicago, December 1933. Publication authorized by the director of the Pennsylvania Agricultural Experiment Station as Technical Paper No. 576.

[2]Professor of plant pathology, The Pennsylvania State College.



Figs. 1 to 6 Photomicrographs of disks used for 10 h continuous spraying with each of the three forms of lime used in this experiment. Figs. 1 and 4 Surface and cross section views of a disk used with stone lime. Figs. 2 and 5 Surface and cross section views of a disk used with pulverized pebble lime. Figs. 3 and 6 Surface and cross section views of a disk used with hydrate. Fig. 7 Photomicrographs of a disk from a spray boom which had covered 1400 acres with stone lime. Fig. 8 From a spray boom which had covered 480 acres with hydrate. It was not deemed necessary to show similar views of an unused disk since such views would approximate very closely the slightly worn ones represented by Figs. 1 and 4

serve, other forms, particularly hydrate, were substituted for the lump form. Recently a finely pulverized form has been placed on the market. The purpose of pulverizing this form was to eliminate the sediment which invariably resulted from slaking. It is evident to any one familiar with slaking such batches of lime that this residue is made up of impurities, the pulverizing of which renders them undetectable by ordinary means and inseparable, of course, in preparation of the spray mixture. It is also evident that any such impurities found in the lump form never get into the Bordeaux mixture for they are of sufficient size to be removed by the ordinary screen which comes with the spray outfit. The cost of either the hydrate or pulverized form is more than the hand-picked lump and neither of them has quite equalled the stone-lime for effectiveness in our tests on potatoes or other crops. The single argument in their favor is that their use does not require a mastery of the art of slaking. Anyone, however, who has a discriminating appreciation of a properly prepared batch of Bordeaux mixture knows there is actually no more labor involved in using one form of lime than another.

Field observations over a period of years have indicated that the various forms of lime resulted in unequal wearing of spray equipment, especially of the disks of the spray nozzles. Accordingly, an experiment was planned to procure data under controlled conditions. A spray boom of ten nozzles was devised to allow for continuous spraying with the several forms of lime used in the preparation of Bordeaux mixture. The equipment was arranged in such a manner that the spray material was collected and pumped over and over. The spray pump was operated at a uniform pressure of 400 lb per square inch at the nozzle for periods of ten hours of continuous spraying. Stone-lime, pulverized lime, and hydrate lime are obtained from the best available commercial sources. Further precautions to secure uniformity in the conditions of the experiment were observed in the selection of the disks for the spray nozzles. The disks used were all the product of one lot of a leading spray manufacturer, so that each series of ten disks represented a random sample, thus possessing as great a uniformity as to hardness, structure, and thickness as possible.

Ten disks were used at a time and the experiment was repeated five times for each of the forms of lime used. Accurate weighings were made of each disk before and after using. It was calculated that 600 gal of Bordeaux mixture passed through the orifice of each disk during the ten-hour period. Any wearing of the orifice walls would be due to the passage of the spray material through them.

Examination of the disks revealed that the orifices were enlarged unsymmetrically, having worn more on the exit than on the entrance of the opening. The erosion appears to be conical (Figs. 2, 3, 5, and 6). It is well known that the spray as it leaves the orifice of a disk is cone shaped, occasioning the rise of the term "the cone of the spray". Apparently the angle at which the orifice wall erodes approximates the angle of "the cone of the spray". It can doubtless be shown that there is a relationship between this conical wearing of the aperture of the disk and the form and structure of the cone of spray which in turn is an element in the effectiveness of the spraying.

While there was a fairly consistent tendency for the wearing of all the disks of each set to be uniform, some of them showed unevenness in wearing. This irregularity, however, was no greater than might be expected from slight variations in hardness of the disks. The original diameter of the orifice on the inside of the disk was not observably enlarged, the wearing being confined to the outside. The final breakdown of the opening is due to the reaming out of the orifice from the exit side until it is cut through to the entrance side of the disk. Finally the thin edge gives way, resulting in an irregular hole, which then makes the cone of spray asymmetrical. (Fig. 8).

The summary of the comparative losses in weight in the following table indicates an instructive relationship between the kind of lime used in the preparation of the spray mixture and the wearing of the disks. The table gives the average weights in grams of 50 disks for each form of lime before and after spraying for ten hours.

	Lump lime	Pulverized pebble	Hydrate
Average weights in grams of 50 disks before using	8.5791	8.5450	8.3170
Average weights in grams of same disk after using	8.5772	8.5325	8.3049
Loss	0.0019	0.0125	0.0121

While the loss in weight may appear too little to be conclusive, it should be noted that most of this loss comes from the orifice or opening in the disk which was originally a comparatively small hole, having a diameter of 0.0465 in. The type and size of the opening in spray disks cannot be overemphasized for the most efficient spraying. It has been shown that size and shape of disk opening, whirl plates, and pressure are inter-related. It is clear that this balance is upset sooner from the use of pulverized and hydrate lime, due to the more rapid erosive effect.

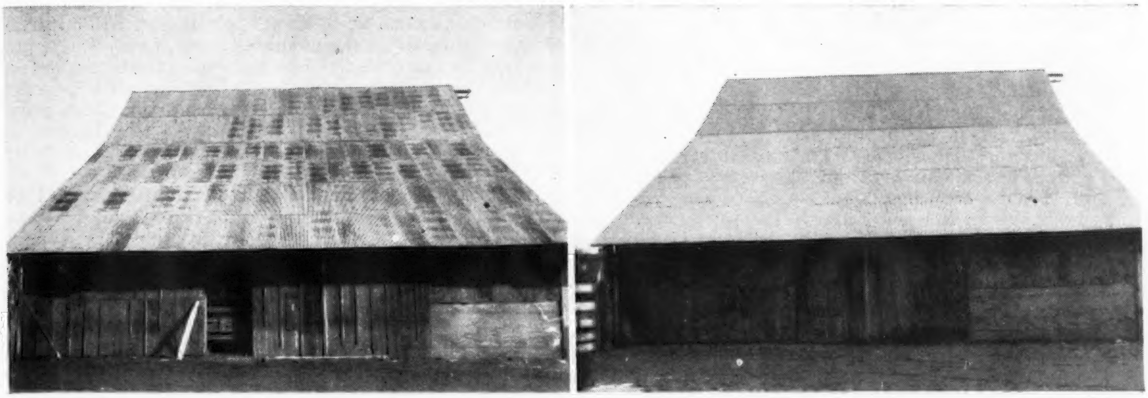
The economic importance of this abrasive effect on the spray disks is best appreciated by anyone familiar with the cost of replacement. The greater loss, however, comes from postponement or neglect in replacing the worn disks, resulting in inefficiency (See Fig. 8).

This differential outlay for disks would presumably extend also to the replacement of plungers, packing, cylinders, and valves.

It can be calculated from these losses in weight for the various forms of lime that, if the same rate of wearing were to continue it would require 66 h to wear off as much in weight with stone lime as was worn off by ground burned lime in 10 h. An application of these calculations to field conditions shows that a ten-row spray boom of 30 nozzles, each discharging 60 gal per hour, would spray in 66 h 118,880 gal of Bordeaux mixture. At the standard application of 150 gal per acre this would cover 792 acres with Bordeaux mixture made from stone lime. In the case of Bordeaux mixture prepared from ground burned lime, the same computations show that only 120 acres would be covered to make the same equivalent in disk wearing.

Actual field conditions approximate pretty closely these calculations as exemplified by Figs. 7 and 8. Fig. 7 is a photomicrograph of a disk which was taken from a sprayer after completing 1400 acres of spraying in which stone lime was used in preparing the Bordeaux mixture, and Fig. 8 is a photograph of a disk which was taken from a sprayer after completing only 480 acres of spraying in which hydrated lime was used in preparing the Bordeaux mixture. There is no telling how long inefficient spraying was going on through the disk represented by Fig. 8, since a symmetrical cone cannot come from such an irregular opening, and furthermore, the proper relationship of disk opening to whirl plate and to pressure has been completely nullified.

(AUTHOR'S NOTE: Acknowledgments are due to Dr. Helen D. Hill for criticism in the preparation of the manuscript, to Dr. J. Ben Hill for assistance in photography, and to the Department of Agricultural Engineering of The Pennsylvania State College for laboratory facilities.)



(Left) A rusted sheet metal barn roof before painting. (Right) Same roof after application of metallic zinc paint

The Use of Metallic Zinc Paint for the Protection of Metal Surfaces

By H. P. Fritsch[1]

THE great destroyer of iron and steel is rust. No one can even approximate the continuing and enormous losses of which it is the direct cause. A tremendous amount of research has been devoted to solving the problem of rust and huge expenditures are made every year to lessen its ravages, but no complete and permanent answer to the rusting problem has ever been found.

This problem has been attacked principally through one of three general methods: (1) Through certain metallurgical treatments of the iron or steel, chiefly by alloying it with another metal, such as copper, so as to retard or reduce the rate of corrosion; (2) through covering it with another metal as a protective coating, and (3) through the use of paints, adapted to metal surfaces, which afford a protective film. The first of these methods acts merely to slow up the rusting process; the second and third, properly applied, will actually prevent rust so long as the protective coating is intact. When the coating is gone, however, it is obvious that rust will attack the exposed areas of the iron or steel surface, and consequently the utmost care should be given to the adequacy and durability of such coatings.

A discussion of the different metallurgical practices designed to retard corrosion will not be attempted in this article, but a brief consideration of coating with other metals is quite apropos, because its use is so widespread on materials that enter into farm building construction. Among the metals used for coating purposes are zinc, copper, tin, lead, cadmium, nickel, chromium, and aluminum, and of these the one most widely used is zinc. U. S. Bureau of Standard Circular No. 80 states definitely that of the common metals zinc is "by far the best" for the rustproofing of iron or steel.

Zinc is easily and effectively applied to the iron or steel surface, gives an impervious, continuous coating, and is the only one of the commonly used metals that exerts a "galvanic" or electrochemical action which prevents the formation of rust even where a small area of the underlying metal is exposed to the atmosphere. It should always be remembered that the life of the zinc coating depends primarily on its thickness, or weight. The heavier the coating, the longer the life; in fact, under ordinary rural conditions it has been found that a relatively small increase in weight of zinc coating will give a much larger proportional increase in durability. For example, doubling the weight of zinc coating may increase the durability several fold.

The protection of metal surfaces by painting has involved the use of many different materials, with widely varied results. A paint for metal surfaces should possess certain distinctive characteristics. Among these are rust prevention, distensibility, hiding power, spreading rate, durability, ease of application, and good appearance.

First of all, a paint used for a "primer" or first coat should be one particularly adapted to metal surfaces. Many paints make excellent finish coats that will withstand exposure to the weather, but are not at all suitable as metal primers, and paints which are well adapted to wood surfaces may not be at all suited to metal surfaces.

Paints in common use for metal surfaces are formulated with various pigments, including red lead, blue lead, lead chromate, zinc oxide, zinc chromate, iron oxide, graphite, metallic aluminum powder, and metallic zinc powder. In addition to these, of course, asphalt and coal tar paints are widely used.

Each of these paints possesses some of the characteristics previously enumerated, but the combination of all of them is possessed to an extraordinary degree by a special paint manufactured from metallic zinc powder. In this paint the metallic zinc powder constitutes approximately 80 per cent of the pigment, the remaining 20 per cent being zinc oxide. The usual vehicle is linseed oil. Both the metallic zinc powder and the zinc oxide are rust-inhibitive. The function of the zinc oxide is twofold. It helps to hold the heavy zinc powder in suspension, and by reason of its finer particle size it gives the paint a more impervious film.

Metallic zinc paint, due to its chemical nature, is extraordinarily effective as a rust-preventive. Zinc in

[1]Secretary-treasurer, Vane-Calvert Paint Company. Aff. A.S.A.E. (Mr. Fritsch is considered the dean of paint technicians in this country and is widely known in the industry.)

the form of galvanizing, as has been stated, exerts an electrochemical or "galvanic" action upon the underlying iron or steel, and apparently this characteristic of zinc is likewise effective when it is applied as a paint film.

The primary factor entering into adherence of paint to a metal surface is the natural "sticking" qualities a paint has for that surface. That metallic zinc paint will adhere to a metal surface has been proven by tests of several years duration, after which careful observations have shown the paint film to be still in excellent condition. Even in the case of zinc and zinc-coated surfaces, which present a particularly difficult problem for most paints, metallic zinc paint has shown remarkably good adherence, even without the pretreatment or etching of the surface which is usually considered essential.

Distensibility of a paint film is that property which enables it to adjust itself to changes caused by expansion and contraction, or mechanical deformation of the underlying metal. The excellent distensibility of metallic zinc paint is demonstrated by the maintenance of an unbroken film after years of exposure on the roofs and sides of metal-clad buildings.

Metallic zinc powder is wholly opaque to ordinary light and when applied in the form of paint will obscure with one coat even the darkest background. This is vividly illustrated by examination of badly rusted surfaces which have been painted with it. On account of this property it is especially valuable for use in covering up metal roofs which have become unsightly by reason of conspicuous rusted areas. In all such cases, of course, the rusted areas should be given a vigorous wire-brushing before the paint is applied.

It is obvious that in order to be economical a paint should cover the maximum of area with the minimum of labor in application. Actual applications of metallic zinc paint have shown the remarkably high spreading rate of 700 to 800 sq ft per gallon, or even more.

Annual Cost Is the Real Measure of Paint Value

The durability of a paint film as a continuing protection to the surface underneath is of extreme importance, for, after all, the cost per year is the real measure of value. Metallic zinc coatings on various metal-clad buildings, exposed to industrial conditions, are still in good condition after four to eight years' exposure; in fact, their present condition indicates a considerably longer life even under these severe conditions. Under the more favorable conditions of rural exposure the durability of the paint is of course materially increased.

Metallic zinc paint works easily and efficiently under the brush or in the spray gun, and spreads with surprising ease. It "levels" very well, without leaving brush marks, and is well adapted to painting wire and other small dimension pieces, where sharp corners or crevices make conditions difficult for ordinary paints.

In appearance the natural color of this paint is a battleship gray, quite similar in appearance to that of a weathered galvanized sheet. The surface of the paint is extraordinarily dense and uniform, and sheds dirt well, thus preserving its handsome appearance.

The advantages of metallic zinc paint as a primer are enhanced by the fact that it makes an excellent base coat in case a finish coat of another type of paint, having some special color, is desired. It is to be noted, however, that best results are to be had by using the same paint for both primer and finish coats, and one of the distinct advantages of metallic zinc paint is that it can be very successfully used in this manner.

Metallic zinc paint is available in either the paste form, which must be thinned with linseed oil and drier before using, or in the prepared form, ready for application. In many cases this paint is now furnished in double-compartment cans, the metallic zinc powder being stirred into the vehicle before using. This powder will not settle into a hard mass at the bottom of the can as is so often the case with other metallic powders.

The surface of the metal to be painted should be dry and warm. Exterior painting should not be done too early in the morning when dew may be present, and to secure the best results should be carried on only in warm weather. Actual experience has shown that the spreading rate is greatly reduced when temperatures are low.

Metal surfaces should be free from grease and dirt and from loose rust. Sand-blasting is the most effective treatment for all conditions of the surface, as it not only cleans but also roughens or "etches" the surface so as to give the paint a good grip.

The Preparation of Metal Surfaces for Applying Paint

In the case of zinc or zinc-coated surfaces, the best method of preparation is to let the surfaces weather for six months or longer. If it is desired to paint these surfaces at once, if already free from grease, they can be readily etched by means of a solution of copper acetate, copper chloride, or copper sulphate, about four ounces to a gallon of water. This solution may be applied with a brush, allowed to dry, and any loose deposit that may have formed should then be carefully brushed off. A more practicable and economical method of cleaning and etching the zinc surface in a single operation, particularly where grease is present, is to apply liberally with an oil-free brush an acidified mixture of approximately the following composition: 60 volumes denatured alcohol, 30 volumes tolurol, 5 volumes carbon tetrachloride, and 5 volumes commercial concentrated hydrochloric (muriatic) acid. This treatment is especially effective and is highly recommended.

It may be of interest to indicate the various reasons why zinc and zinc-coated surfaces usually require special treatment before painting. Among these are: (1) the presence of oils or grease due to handling of the sheets or as lubricants applied in their manufacture, (2) the inherent smoothness of the zinc surface when new, (3) certain physical characteristics, such as the relatively high coefficient of expansion of zinc and the comparatively low coefficient of expansion of certain primers, and (4) certain progressive reactions that may take place between the paint itself and the zinc surface. Under certain circumstances difficulty may be caused by any one of these factors or by a combination of any of them, so that it is essential in the painting of zinc surfaces to take all of them into consideration and provide accordingly. The methods outlined above are offered as suggestions although these constitute only a few of the possible methods.

As stated before, metallic zinc paint, probably due in part to its chemical composition and in part to its unusual distensibility, affords much better adherence to zinc and zinc-coated surfaces than many other paints commonly used for the purpose.

The whole subject of painting sheet metal and structural iron and steel is one of extreme importance and always merits the most careful attention. This is especially true in the agricultural field where every year rust destroys millions of dollars' worth of property—roofs, machinery, tanks, gates, windmills, etc. It is always real economy to use only the best paints, especially adapted to the work in hand.

New Process for Making Zinc Coated Farm Fencing More Durable

By J. L. Schueler[1]

IN general, woven wire fences on farms are brought to the end of their useful life by corrosion. The problem of the engineer, both in designing fencing and controlling the properties of its materials, and in counselling its selection for specific applications, is to arrive at the most economical relation between useful life and overall cost of purchase, installation, and maintenance.

From the standpoint of corrosion resistance alone, steel is one of the poorest of common materials that could be selected. Yet no other economically available material affords the necessary physical properties such as tensile strength, workability, etc. Hence, with steel to furnish the necessary strength and an adequate protective coating to furnish resistance to corrosion, woven wire fencing has the best qualities of both.

The corrosion of steel, and in general all other metals as well, is affected by the natural influence of climate, and by certain man-made contributions to, or pollutions of, the atmosphere. Like many chemical reactions, rusting proceeds more rapidly as the temperature increases. Humidity also accelerates corrosion. Where these two influences are combined, as, for instance, along the Gulf of Mexico, corrosion is relatively rapid.

Corrosion is more severe in air containing smoke or other industrial gases. Those gases which contain, or oxidize to produce, sulphuric acid, seem to be the worst offenders. Coal of all kinds contains varying but appreciable amounts of sulphur, and the amount of atmospheric gases coming from the combustion of coal is a material factor in the rapidity at which wire fencing corrodes.

The most practical and economical method of protecting steel fence wire from corrosion is to coat the wire with zinc, which the U. S. Bureau of Standards states is "by far the best" protective metallic coating for the rust-proofing of iron and steel. This process, strangely enough, is called galvanizing although there is nothing galvanic about it, no electricity being used in the application of the zinc. However, we will see later that galvanism, or electrolytic action, does play a part in the subsequent protection of the steel by the zinc.

The main purpose of the zinc coating is to seal the inclosed wire from the air and moisture with a layer of highly impervious material which itself is sufficiently resistant to corrosion to have a reasonably long life. Other things being equal, a *thick* coating of zinc will take longer to be consumed by corrosion and so will protect the steel for a longer period than a *thin* coating. Unfortunately, however, the fence manufacturer cannot improve his product merely by yielding to a generous desire to put on more zinc. Zinc coatings are inherently brittle, especially if they are heavy.

The secondary purpose of the zinc coating is to divert corrosion from the steel by electrochemical action. This it does by virtue of being electro-negative toward steel. If a strip of zinc and a piece of steel are immersed in a glass of water to which a few drops of sulphuric acid have been added, we have the familiar classroom example of a voltaic cell. If the two metals be brought into contact with each other, or connected by a wire to form a closed circuit, an electric current flows from zinc to steel through the liquid, or electrolyte, and as long as the zinc remains the steel is protected from attack by the acid.

If the zinc is replaced by some metal which is electro-positive toward steel, such as tin, lead, or copper, the current reverses its direction of flow, and the steel, instead of being protected, is consumed, as was the zinc in the first case.

A wire fence is a collection of just such short-circuited voltaic cells, infinitely small. Exposed surfaces of steel, such as cut ends, tool marks, and microscopic pores through the zinc coating, are wet with rain or dew which has absorbed sulphuric acid and other corrosive substances from the air. If the drop or film of moisture also touches the zinc, the corrosion is diverted from the steel. It is important to remember that such protection of the steel is accomplished at the expense of consuming the zinc.

The rate at which the zinc is consumed, in addition to the direct weathering action which would occur with zinc alone, is governed in considerable part by atmospheric conditions which are beyond control. This rate also is affected by the area and distribution of the bare spots on the steel. As long as these bare spots are few and small, the burden of *protection imposed on the zinc* is diminished. When the zinc is nearly all used up, or for any reason the area of exposed steel increases, the remaining zinc is very rapidly consumed. Then the steel rusts away at a rate controlled only by its individual rust-resisting properties.

In this connection it has been found that rusting under atmospheric conditions proceeds much more slowly with steel into which 0.20 to 0.30 per cent of copper has been incorporated during its manufacture. There is abundant experience to prove that steel with this content of copper has substantially longer life.

Among these experiences, the results of certain well-controlled tests made by the American Society for Testing Materials are outstanding. Under various climatic conditions, typical of those to which woven wire fencing is subjected in actual use, these tests showed that the addition of 0.20 to 0.30 per cent of copper increased the life of steel from one and one-half to three times.

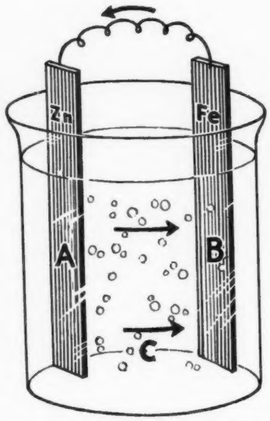
Applying Zinc Coating to Steel Wire Is a Difficult Process

Unfortunately the only way to determine the durability of wire fencing is by actual test in a specified locality. We have useful tests to guide and control processes of manufacture, such as the Preece or copper sulphate test which determines the *uniformity* of zinc coating, and stripping tests, such as that specified by the American Society for Testing Materials, which determine the *weight* of zinc coating. These tests also may be used to determine whether samples of wire conform to purchase specifications on these points. But the fact remains that we have no laboratory or other accelerated tests which will surely and accurately predict the life of a fence under actual service conditions.

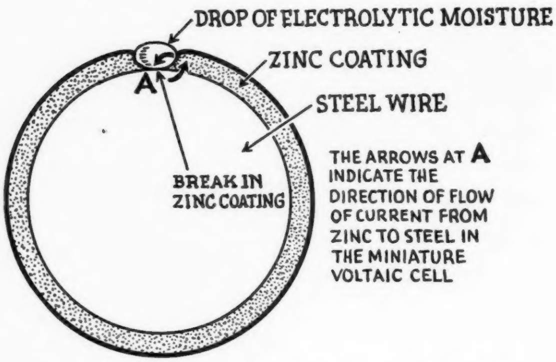
The application of a zinc coating to steel wire is not a simple nor an easy matter. As has been men-

[1]Chief metallurgist, Continental Steel Corporation, Kokomo, Indiana.

tioned, the inherent brittleness of such a coating, which is in effect a zinc casting, precludes the use of a very heavy coat. As the wire comes from the bath of molten zinc, it not only carries too much of the coating metal, but the latter is rough and irregular in thickness. The traditional method of thinning and smoothing the coating is to pass the wire through "wipes" before the zinc solidifies. In principle this is sound enough, but in practice it has always been extremely difficult to keep the wipes from removing most of the zinc. Even worse, perhaps, is the tendency of the wipes to increase the number, even if they reduce the size, of minute pores or pinholes through the coating.



A-ZINC PLATE B-IRON PLATE
C-ELECTROLYTIC SOLUTION



(Left) Showing the electrolytic action between zinc and iron in a voltaic cell. (Above) Diagrammatic representation of electrolytic action between zinc and steel in zinc-coated steel wire

It should be remembered that metals, particularly in thinly deposited layers, seldom are completely impervious in a chemical and microscopic sense. It is a matter of common observation, for example, that ordinary nickel plating applied directly on steel is sufficiently pervious to admit moisture and gases which cause rusting. While zinc coatings are not so susceptible to this condition, they are however no exception to this propensity; it is one of the problems with which the fence makers must contend.

In order for the zinc to adhere to the wire, the surface of the steel must be made chemically clean. The steel itself must have certain physical and chemical characteristics if the coating is to adhere permanently and firmly. The precise physical and chemical mechanism by which the zinc is bonded to the steel is, in my observation, unimportant as long as it is effective.

It should be apparent that making a durable fence involves much more than merely applying an abundance of zinc. Economy in material is not the controlling reason for limiting the amount of zinc used on better grades of fence. Even though zinc costs more per pound than steel, it is by no means a precious metal. There is a general purpose apparent among the makers of good fencing to use all the zinc that will prove economic in prolonging the life of their product.

Studies Show There Is a Critical Value for Zinc Coating

It may be helpful to refer to findings arising from studies by the American Zinc Institute, as presented to members of the Structures Division of the American Society of Agricultural Engineers by G. C. Bartells. In these studies, which had to do with galvanized sheets used for roofing under rural conditions, it appeared that there is a rather well-defined minimum or critical value for thickness of coating. Any coating thinner than the minimum began to rust in abnormally short time, and the useful life of the sheet was soon ended; while amounts of zinc above the critical value seemed to be economically justified, in increasing the rust-free service life by periods considerably out of proportion to the increases in weight of coating.

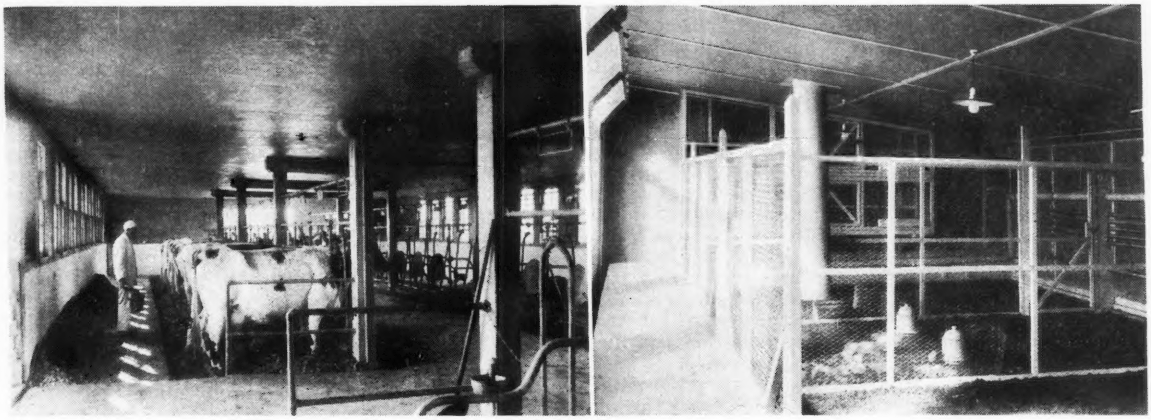
Specimens of long-lived sheets approaching destruction by loss of zinc through years of weathering showed a faint color of rust in the zinc coating itself, seeming to indicate a plane immediately adjacent to the steel surface in which a certain small amount of iron was alloyed with the zinc. This raises the question as to whether such mixtures of iron with zinc may extend clear through coatings of less than critical thickness and somehow contribute to their early failure, or whether the premature failure of thin coatings should be ascribed solely to the difficulty of attaining consistently satisfactory imperviousness.

There are too many differences in the composition and treatment of the steel and in the methods of coating to borrow, ready made, conclusions from studies of galvanized sheets and apply them without verification to wire. Nevertheless these studies of sheets do give a degree of corollary support to the belief that uniformity and imperviousness of coating are important factors in addition to heavy coatings in increasing the service life of wire fencing.

These points have been thoroughly considered in the development of a new method of zinc coating with which the writer has been connected. The process begins with a complete control of the analysis of the steel in a specially manufactured wire; that is, the composition incorporates those elements in correct amounts, which give the steel the qualities essential for good fence. Before coating with zinc, this wire is given a heat-treatment by passing it through a bath of molten lead, held at a temperature which develops certain desired physical properties in the steel wire. There is no chemical significance in the use of lead. Molten lead is merely a neutral liquid of high heat conductivity suitable for use in bringing the wire quickly and uniformly to exactly the right temperature without severe oxidation.

After leaving the molten zinc bath which gives the wire its coating, the wire is "flame sealed"; that is, it is subjected to the action of a flame which evens the distribution of the coating around the wire, smooths the coating, and, at the same time, seals up any pin holes or other voids in the coating before the latter completely solidifies. The coated wire is then ready for weaving into fence.

While the improved regulation and uniformity of distribution permit a greater average and, more particularly, greater minimum thickness of coating without running into the difficulties that attend heavy coatings, it is believed that the greatest contribution to extended life by the flame-sealing process is the relative impermeability which it produces. This (and also the use of slow-rusting steel) should so reduce the burden of electrolytic protection by the zinc as to decrease sharply the consumption of the latter and correspondingly prolong its protective action.



The interior walls and ceiling of this dairy stable and poultry house are provided with an insulating material

Status of Heat Insulation Development[1]

By Russell E. Backstrom[2]

COMMERCIAL heat-insulating materials may be classified roughly as follows: (1) Rigid, of which there are two types, structural (or insulating building board) and nonstructural, (2) semirigid, (3) flexible, (4) fill, and (5) metal foil. The present high plane of development in this field of materials is the result of years of research on the part of individuals, technical schools, scientific organizations, and commercial concerns. We have long recognized the need for building products that make warm dwellings possible and to this end have, in years past, resorted to the use of sawdust, shavings, straw, and other materials. We have not thought of these as insulating products particularly, but knew that through their use houses were made more comfortable in winter and that stored ice, fruits, or vegetables were better preserved in warm weather.

Today building products made for the express purpose of insulating against heat or cold and manufactured with a predetermined capacity for retarding heat flow are available for every insulation requirement. It is possible to calculate with mathematical preciseness the effectiveness of such materials in saving fuel in heated buildings and in conserving refrigeration for cooled structures. The application of insulation to buildings heated or cooled artificially is accepted practice.

A description of each of the above-mentioned classes of insulation is outside the scope and purpose of this paper. Information is available from a number of different sources, such as the literature of manufacturers and various publications of state universities and the federal government.

Commercial Standard. It is in keeping, however, to call attention to improvements and developments in connection with these materials. One important step forward is the adoption by that part of the industry manufacturing rigid structural insulation of a standard specification governing the physical properties of its products. Until a few months ago, there was no "standard" by which to judge insulating boards, and the great variability in thermal properties, strength, etc., between products of different manufacture resulted in confusion in the minds of consumer and producer alike.

To add to the disorder, many materials that resemble insulating board were called "insulating materials," whereas some were too dense or too thin to have a high degree of insulation value. In order to define the material "insulating board" and to establish minimum values of its properties, the manufacturers sought the cooperation of the U. S. Bureau of Standards in establishing a standard specification governing the physical characteristics of these materials. The adoption of such a standard in May 1932 marked a significant development in this field. Now the consumer knows that any material bearing the stamp of "Certified Insulation" will meet the following minimum requirements[3]: Conductivity (maximum), 0.36 Btu per hour per square foot per degree F per inch of thickness, when dry samples are tested at a mean temperature of 75 deg; thickness, 13/32 in; water absorption (maximum), 5 per cent by volume, when submerged under 1 in of water for two hours; average tensile strength, 175 lb per square inch; deflection (maximum), 1/10 in in span of 8 in when loaded at the midpoint with 10 lb weight; plaster adhesion (gypsum plaster), 600 lb per square foot; linear expansion (maximum), ½ per cent when placed in atmosphere at 93 per cent relative humidity for 24 h, after being conditioned in air at 32 per cent relative humidity.

In addition to serving as a basis for manufacture, and as a guarantee to the consumer, this standard should serve as a yardstick to the engineer for comparing the different makes of materials. Although all materials bearing the "certified insulation" stamp fall within the minimum requirements, certain makes naturally will excell in some of these properties. The different boards may be tested in accordance with the standard tests prescribed by the specifications and a comparison made of those properties which should dominate for the particular use in mind, whether it be sheathing, plaster base, or thermal insulation only.

Metal Foil. Another new development in the field of insulation and one which is a radical departure from the commonly accepted practices, is the use of

[1]Paper presented at the 27th annual meeting of the American Society of Agricultural Engineers held at Purdue University, Lafayette, Indiana, June 1933.

[2]Insulation specialist, National Committee on Wood Utilization. U. S. Department of Commerce. Assoc. Mem. A.S.A.E.

[3]From Commercial Standard CS42-33, "Fiber Insulating Board," issued by the Bureau of Standards, U. S. Department of Commerce.

thin sheets of bright metal. The principles involved—that bright metallic surfaces are good reflectors and poor emitters of radiant heat—have had practical application for a number of years. The vacuum bottle with its silvered lining and the polished metal covering on vessels containing high-temperature fluids or gases are familiar examples. The possibility of using these same principles in connection with heat of long wave-length as encountered at ordinary atmospheric temperatures has been largely overlooked. This fact coupled with the lack of appreciation, generally speaking, for the rather large proportion of the heat transferred by radiation across air spaces in wall and roof construction, has until recent years caused this particular field of investigation to be neglected. We know now, however, that as much as 75 per cent of the heat movement across such spaces is by radiation and that bright metallic surfaces are effective in reflecting back to the surface from which it came, a large part of the heat that reaches the inside of walls. We know further that such surfaces are effective because they refuse to give off heat easily.

Since the two properties—high reflectivity and low emissivity—upon which metals depend for their insulating properties are entirely surface effects, the surface of metals used for this purpose should remain bright more or less permanently.

Improved Insulation. Other recent changes in the field of insulation have to do more with improvements in the already available materials. For example, board insulation in some instances is treated chemically to be resistant to decay and to termite attack; it is sometimes treated to be fire-resistant either by coating the fibers with a noncombustible material or by covering the surfaces of the panel with a layer of asbestos or other mineral material; sheets of steel cemented to the surfaces have the two-fold effect of excluding moisture and adding strength to the unit; thin sheets of metal foil cemented to one or both surfaces also are effective in shutting out moisture, and in addition enhance the total insulating value of the product.

Some of the Improvements in Insulating Materials

A recent change in the method of covering flexible insulation makes a more waterproof product since the edges as well as surfaces are now covered with asphalt-coated paper. Packages of insulation with a "core" of flexible, fill, or rigid insulating material thoroughly wrapped in asphalt-coated paper, and sealed to exclude all moisture, are available for use where moisture conditions are extremely severe, such as cooling tanks and refrigerators.

Fill insulation is now available in the form of "batts" two or more inches thick that may be installed in much the same manner as covered flexible material.

To this list of improvements in the insulating materials themselves should be added the greater ranges in sizes and thicknesses in which the different materials are now available. Non-laminated panels of insulating board, ¾, ⅞, 1, and 1½ in thick, are on the market in addition to the standard ½-in thickness. Laminated insulation made by glueing or stapling together layers of ½-in boards until any desired thickness is reached is available in special widths and lengths.

At the other extreme of thickness are materials that cannot be classified as insulation since they are thinner than the minimum allowable under the commercial standard for fiber insulating board and also exceed the conductivity limit. They are interesting, nevertheless, and are closely allied to insulating boards since the former are made from the same fibers and in much the same manner as insulating boards. Such materials are known as "pressed boards" or "hard boards." Because the fibers are firmly compressed, these materials have great strength and little insulation value. They are available in thicknesses ranging from ⅛ to 5/16 in, and are suitable for outside finish and many construction uses where regular insulating board does not qualify.

Aside from the more or less standard lengths and widths, insulating board is now being sold in many different dimensions to meet various use requirements. There are units eight or more inches square, as well as rectangular pieces, with edges beveled for use as interior finish in dwellings, churches, and public auditoriums; also, "planks" in widths of from 4 to 12 in and lengths of 8 ft or more with long edges beveled, for this same purpose.

Insulation for Dwelling Houses in Both North and South

Insulation in Dwellings. In dwelling houses, the use of insulation is gaining with the apparent need in both the North and the South for materials that give effective control over temperature. In the North, because of the long heating season, insulation is particularly desirable from the standpoint of fuel saving. Especially is this true if expensive fuels are used, and in fact, the practical use of the more expensive fuels is dependent upon how well the house is insulated. Fuel saving is an addition to the comfort that accompanies warm walls. Cold walls and windows, as shown by tests, are the source of much discomfort to occupants, due to radiation from the cold surfaces, even though the air be at a desirable temperature.

The advent of air-conditioning for dwelling houses further emphasizes the need for insulation. At the present time, summer conditioning involving cooling is still usually more expensive than winter heating, hence walls that resist well the passage of heat from the outside to the inside are highly desirable. Further, the exclusion of warm air that passes by infiltration through the wall or around the windows and doors is important. These two factors—warm walls and tight walls—are often necessary to the successful and economical operation of the system. With the greater need for summer cooling in warm climates, the desirability of insulation there is obvious.

But aside from its use in connection with air-conditioning, there is a real need for these materials in buildings in the South. There, walls and roofs with low insulating value are frequently used. High-ceilinged rooms and the use of shutters or awnings for windows aid in combatting heat in these houses, but more comfortable conditions in both summer and winter could be obtained if walls and top floor ceiling (or roof) were adequately insulated. In this case, the cost of construction might be lessened by building rooms with ceilings only 8 to 9 ft high, which would represent a saving in both material and labor.

New Types of Construction. No discussion on the use of insulation in dwellings would be complete without considering the new construction types and methods now being offered. New ideas in building construction are being developed with a view to reducing costs through (1) prefabrication, thereby effecting a saving in labor, (2) the use of lightweight materials, reducing transportation and handling costs, and (3) the use of the right materials properly applied.

Without going into too much detail, let us examine several of the new construction types. One of the simplest consists of framing of steel tees and channels with panels of steel-covered insulation inserted between. With 1½-in thick insulation panels, such a wall is equivalent in heat-resisting capacity to many non-insulated walls now in use and considered to be "fair" walls. A slightly more elaborate construction, but along the same general lines, consists of standard

insulating board covered outside with sheet steel and inside with plywood.

Another type of steel-wall construction is frameless, i. e., units of sheet steel are pressed into rectangular corrugations, and the box-like spaces filled with a loose fill insulation. Outside the corrugations is placed a layer of insulating board protected with enameled metal, and inside, a layer of plaster board, papered or plastered.

A modified type of wood construction consists of aluminum foil placed over the outside edges of the studding and the foil covered with insulating board sheathing. Insulating board is also used as inside sheathing. From this brief description, it may be seen that the natural capacities of the materials are utilized to the highest degree in the new construction types. Insulation in some form is considered one of the essentials.

Farm Structures. The agricultural engineer is interested in new ideas pertaining to construction, since much of his work is in the planning of buildings to give the maximum return on the investment. Many of the new methods suitable for dwellings will also be applicable to barns and storage houses. Usually, cost is an important item and in many cases it is either a low-cost building or no building.

In this connection, reference is made to two reports that should be of particular interest to structures men. One report is "Modern Connectors for Timber Construction"[4], and the other, "The Heat Conductivity of Wood at Climatic Temperature Differences"[5]. The first mentioned report describes methods of joining wood members so that the joints, which usually are the weakest part of a wood structure, are increased in load-bearing capacity from four to eight times that of ordinary bolted joints. Economies in material and labor result from the use of this system.

The second report mentioned gives the results of four years' work by Professor Frank B. Rowley, director, experimental engineering laboratories, University of Minnesota, in the testing of various species of wood. The work is a cooperative project of the University of Minnesota, the American Society of Heating and Ventilating Engineers, and the National Lumber Manufacturer's Association.

The report gives the results of hundreds of tests on a large variety of commercial species of both hardwoods and softwoods and shows the conductivity at various moisture contents. The report has a very practical application in the design of animal shelters and storage houses since it is now possible to determine heat-resisting capacity of walls more accurately, and also to select a species of lumber that will give the greatest possible insulation value.

Men interested in rural electrification will also find this latter report valuable in the design of refrigerators and cooled structures. These men particularly appreciate the value of the insulating materials previously described where a "core" of material of high-insulation value is wrapped and sealed in waterproof paper. Such products find ready application in milk-cooling tanks, boxes for chilling meat, or refrigerators for the quick freezing of meats, fruits, or vegetables. The use of refrigerated truck bodies in collecting milk and perishable products is increasing rapidly, and insulated bodies are highly important where the products are transported for considerable distances.

SUMMARY

In conclusion and briefly summarizing with regard to the status of insulating materials, it may be said that the industry is making every effort to keep abreast of the times through (1) the adoption of a standard specification fixing the minimum values of physical properties of the rigid structural type; (2) adopting new materials for use in themselves or in combination with others to enhance the value of the products already available; (3) improvements in special properties such as waterproofness, fireproofness, and resistance to decay and termites; (4) increased thickness of non-laminated board, and the offering of greater thicknesses of laminated products, both of which have greater practical value as structural material, and (5) a wider range in dimensions of boards which are in themselves suitable for interior finish such as the so-called "tile" and "plank". New insulating materials and improvements in the old products are of particular interest to the agricultural engineer, since they help solve many problems in the construction of dwellings, animal shelters, storage houses for fruit and vegetables, refrigerators, and every other problem where temperature differences are involved.

[4]Issued by the National Committee on Wood Utilization, U. S. Department of Commerce.

[5]The American Society of Heating and Ventilating Engineers Journal in Heating, Piping and Air Conditioning, June 1933.

The Engineer an Individualist

THE engineer must be an individualist; he cannot be otherwise and accomplish the results with which he is credited. He must necessarily go his own way, make his own decisions, fight for them if necessary, and hold to his conclusions. Unless he cares more for his reputation than his fee, he is false to his profession and not worth the fee his client pays him. He is consequently generally underpaid and acquires wealth only by shrewd investments or by entering the business phases of engineering. Although he is an individualist in respect to himself, he has long recognized the value of cooperation, has generously supported public projects, and has devoted much of his time to his professional societies. Yet he believes that each man must stand on his own feet; he welcomes advice, but does not ask for help, and has little respect for the man who cannot help himself.

He does not believe in panaceas and knows the inertia of man as well as the inertia of the steam hammer or the river flood. He knows that great expenditures offer greater inertia than small ones, and that just as half the cost of the structure frequently lies in the foundation out of sight below ground, so any great project must have its period of slow progress for planning and foundation, if trouble and delay are to be avoided. . . . .

The engineer has been trained to reason from facts to a sound conclusion, and because of his impatience with the lack of such reasoning, he has been forced to add business and the social sciences to his studies. It is he who initiated and is leading in the development of the science of industrial management. Just as his machine has been misused, so this budding science has been seized upon as a means of quick profits rather than a basis for sound planning for an equitable division between the employer and the employed. . . . . . The engineer has proved himself a sound analyst of business methods and has put the scientific method into management; possibly he must assume the responsibility of making order out of the present chaos in the study of economics. He must at least recognize his responsibility to industry and civilization and realize that if new jobs are needed, he must create them; but he cannot create jobs if he does not know how to make one for himself.—W. A. Shoudy in "Mechanical Engineering" for December 1933.

A Review of Progress in Farm Sanitation

By R. W. Trullinger[1]

THE work in rural sanitation as conducted by the U. S. Department of Agriculture, the state agricultural experiment stations, and the state agricultural extension services, has been actively in progress for about 25 years and has been both investigational and educational in character. The problem is essentially one of individual farm sanitation as distinguished from rural community sanitation in the sense usually considered by state and federal health agencies. The main purpose has been to combine convenience, comfort, economy, effectiveness, and safety in water supply, sewage disposal, and heating and ventilating systems, and to insure cleanliness and safety from disease transmission in the production of animal food commodities.

The general problem is complicated frequently, for example, by the necessity for the disposal of dairy wastes, especially in the more distinctly dairy-farming regions such as occur in wide areas of Wisconsin. In recent years, also, the problem of the relation of ventilation and heat and humidity control in dairy cow and poultry shelters to the quality of poultry and dairy products, and the incidence and spread of diseases among such stock which may be transmitted to man, either directly or through their food products, has assumed considerable importance.

Perhaps the most difficult feature of the farm sanitation problem is the fact that in most cases it involves the development of small individual units of equipment and individual processes to meet widely varying conditions on different farms and in different localities.

A study was begun by the U.S.D.A. Office of Experiment Stations of the general situation in 1912 and much of the earlier work was found to be based upon a rather speculative scientific foundation. There was a great demand at that time for authentic information, for example, on how to secure clean water on the farm and on how to dispose of farm sewage and wastes in a safe and sanitary manner. Quite a number of engineers, trained in the accepted theories and principles of water supply and sewage disposal, attempted to adapt to farm conditions sanitary principles which were developed primarily to meet municipal or at least large community needs. Their efforts were attended with rather indifferent success in most cases, as one would expect, especially with reference to sewage disposal.

Unfortunately the demand for information was so great that much of this early immature work was published and put into the hands of extension workers. In fact, if I remember correctly, I myself was the author of one or two official publications relating to various and sundry features of farm sanitation which were published about 1913 or 1914 and which advanced certain findings and principles which later experience proved to be somewhat immature.

Another factor retarding progress in the work was the tendency of engineers to overlook the importance of chemistry and bacteriology in much of the work. For example, in sewage disposal the problem was to liquefy the waste so that it could be disposed of finally at minimum expense and trouble by application to the land either by surface flooding or by subsurface absorption through loose-jointed tile. Subsequent experience demonstrated the importance of considering fully the bacteriological principles in both liquefaction and final disposal, particularly in view of the widely variable character of soils with reference to absorptive and oxidizing capacities. For example, it was found in some semi-arid regions that oxidation of liquid sewage in soils proceeded in an entirely different manner than in humid regions. The handling of water supply problems in order to secure clean water for domestic use and for use in dairies under a wide variety of farm conditions also called for considerable modification of our point of view.

In more recent years some of the state agricultural experiment stations have joined forces with the state boards of health and state water commissions in the study of water supply and sewage disposal problems, with the state dairy commissions in the study of clean milk production, and with state livestock sanitary boards in the production of clean meat and poultry products. These undertakings have brought together the efforts of agricultural engineers, sanitary chemists and bacteriologists, and commodity specialists, and have resulted in the formulation of quite a number of principles and practices covering a wide scope of conditions and which have materially improved the sanitary conditions of farms and farm commodity production practices in general.

For example, the Kansas agricultural experiment station made quite a thorough study of the average daily and monthly volume of sewage flow on typical farms of various sizes and descriptions, and followed this by a study of the character of the sewage and its purification requirements. The work at the Illinois station dealt especially with the establishment of the principles of small-scale liquefaction of sewage as an important feature in its disposal. Other stations have studied other specific features of rural sanitation in the same manner, until a rather substantial background of information is now available which has the aspects of authenticity.

Much of this body of information has been published from time to time, and that part of it adapted to popular consumption has been made available for use by extension workers. Notable examples of extension work are those being carried on by the extension services of Pennsylvania State College and Cornell University.

Following this article is a selected bibliography of publications issued the past ten years which will give a cross-sectional view of the character and quality of both the research and extension work in the subject. This list is not complete, but is representative of the better work in progress.

Much remains to be done in farm sanitation, particularly in the research features. The securing of clean water is developing new and important aspects daily. Notable among these is the discovery a few years ago at the Arizona station of the action of fluorine compounds in water in the destruction of human teeth. The so-called alkali disease of animals, poultry, and humans in some of the middle northwestern states is being traced to certain selenium compounds in soils and water which are synthesized by plant metabolism processes into highly poisonous materials.

The extension field also needs broadening and strengthening, but the research to supply extension workers with authentic data and information seems most important at this time, even though much labor could be employed in the widespread installation of

[1]Assistant in experiment station administration, senior agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture. Mem. A.S.A.E.

such equipment as the Kentucky sanitary privy or the Pennsylvania sewage disposal system.

PUBLICATIONS ON RURAL SANITATION

Water supply and sewage disposal

The design and construction of masonry water supply tanks. H. Giese and J. B. Davidson. Iowa Sta. Bul. 302 (1933).
Studies of bacterium coli in privately owned rural water supplies. R. L. France. Jour. Bact. 25 (1933) No. 6, pp. 625-635. Contribution from Massachusetts Experiment Station.
Stream pollution by irrigation residues. C. S. Scofield. Industrial and Engin. Chemistry, 24 (1932), No. 11, pp. 1223-1224. Contribution from U.S.D.A. Bureau of Plant Industry.
A comparison of the pollution and natural purification of the Connecticut and Delaware Rivers and the Brandywine Creek. L. R. Setter. New Jersey Sta. Bul. 545 (1932).
Soft water for the home. A. M. Buswell and E. W. Lehmann. Illinois Sta. Circ. 393 (1932).
Water Survey of Texas County, Oklahoma. H. W. Houghton. Oklahoma Panhandle Sta. Bul. 20 (1930).
A system for the bacteriological examination of water. A. J. Salle. Jour. Bact. 20 (1930), No. 6, pp. 381-406. Contribution from California Experiment Station.
Pure water is essential to health. W. L. Mallmann. Michigan Sta. Quart. Bul. 12 (1930) No. 4, pp. 134-138.
Turn on the water. F. W. Duffee and J. P. Schaenzer. Wisconsin Agr. College Extension Circ. 229 (1929).
The installation of farm water systems. J. P. Schaenzer and F. W. Duffee. Agr. Engineering 10 (1929), No. 11, pp. 361-363. Contribution from Wisconsin Experiment Station.
Modern water purification methods for the dairy. M. F. Corin and E. S. Hopkins. Agricultural Engineering 11 (1930), pp. 19-22. A.S.A.E. contribution at National Dairy Industries Exposition at Toronto, 1929.
Water carried for household purposes on Nebraska farms. M. R. Clark and G. Gray. Nebraska Sta. Bul. 234 (1929).
Mottled enamel in Arizona and its correlation with the concentration of fluorides in water supplies. H. V. and M. C. Smith. Arizona Sta. Technical Bul. 43 (1932).
Relation of the method of watering dairy cows to their water consumption and milk production. T. E. Woodward and J. B. McNulty. U. S. Dept. Agr. Tech. Bul. 278 (1931).
The cause of mottled enamel, a defect of human teeth. M. C. Smith, E. M. Lantz, and H. V. Smith. Arizona Sta. Tech. Bul. 32 (1931).
Water systems for farm homes. F. D. Cornell. West Virginia Sta. Circ. 44 (1927).
Running water in the farm home. M. R. Lewis. Idaho Agr. College Ext. Bul. 66 (1926).
Water and sewerage systems for Florida rural homes. F. Rogers. Florida University Agr. Extension Bul. 46 (1926).
Water supply and sewage disposal systems. I. D. Wood. Nebraska Agr. College Extension Circ. 723 (1926).
The farm water supply. Part II, The use of the hydraulic ram. F. G. Behrends. New York Agr. College (Cornell) Extension Bul. 145 (1926).
Farm water supply and sewage disposal in West Virginia. F. D. Cornell. West Virginia Sta. Bul. 206 (1926).
A septic tank. E. R. Gross. New Jersey Agr. College Extension Bul. 52 (1926).
Character of the ground water resources of Arizona. C. N. Catlin. Arizona Sta. Bul. 114 (1926).
A study of factors affecting the efficiency and design of farm septic tanks. E. W. Lehmann, R. C. Kelleher, and A. M. Buswell. Illinois Sta. Bul. 304 (1928).
Septic tanks for farm sewage disposal. F. L. Cooper. Colorado Agr. College Extension Bul. 247-A (1926).
Waterworks for Texas farm homes. M. R. Bentley. Texas Agr. College Extension Bul. 67 (1926).
Observations on the Michigan septic tank. O. E. Robey. Michigan Sta. Quart. Bul. 9 (1926), No. 1, p. 22.
Farmstead water supply. G. M. Warren. U. S. Dept. Agr. Farmers' Bul. 1448 (1925).
Water and plumbing systems for farm homes. E. W. Lehmann and F. P. Hanson. Illinois Sta. Circ. 303 (1925).
Farm water works and sewage systems. T. B. Chambers and M. L. Nichols. Alabama Polytechnic Institute Extension Circ. 80 (1925).
Aeration studies on creamery waste purification. M. Levine, L. Lopeland, and G. W. Burke. Iowa Engin. Expt. Sta. Bul. 68 (1923).
Sewerage systems for farm homes. N. S. Fish, E. G. Hastings, and F. R. King. Wisconsin Agr. College Extension Circ. 173 (1924).
Investigations of farm sewage disposal systems. R. H. Driftmier. Agricultural Engineering 5 (1924), No. 10, pp. 232, 233. Contribution from Kansas Expt. Station.
Simple water systems. O. E. Robey. Michigan Sta. Circ. 64 (1924).
Electrical house pumping systems. G. C. Blalock and D. D. Ewing. Purdue Univ. Engin. Extension Service Bul. 4 (1923).
A farm septic tank. W. B. Herms and H. L. Belton. California Sta. Circ. 270 (1923).
The septic tank. E. R. Gross. New Jersey Stas. Circ. 267 (1933).
Proper size of septic tank insures good service. Illinois Sta. Rpt. 1932, pp. 177, 178.
Disposal studies for milk products waste. E. F. Eldridge. Engin. News-Record 106 (1931), No. 13, pp. 520, 521. Contribution from Michigan Engin. Expt. Sta.
Water supplies and sewage disposal. New Jersey Stas. Rpt. 1930, pp. 58, 59.
Sewage disposal for rural dwellings. Ohio Agr. College Extension Bul. 112 (1930).
Milk products waste treatment. Rept. No. 3. E. F. Eldridge. Michigan Engin. Expt. Sta. Bul. 36 (1931).
I. Influence of diluting water on the biochemical oxygen demand.
II. Digestion of sludge from strawboard waste. E. F. Eldridge and W. L. Mallman. Michigan Engin. Expt. Sta. Bul. 39 (1931.
Sewage disposal for North Dakota farm homes. C. L. Hamilton. North Dakota Agr. College Extension Circ. 103 (1931).
A field study of farm septic tanks. California Sta. Rpt. 1931, p. 50.
Action of enzymes on sewage solids. N. S. Chamberlin. New Jersey Stas. (1930).
Studies of the septic tank method of sewage disposal for isolated homes. H. B. Walker and R. H. Driftmier. Agricultural Engineering 10 (1929), Nos. 8, pp. 256-258; 9, pp. 300-302. Contribution from Kansas Experiment Station.
Sludge accumulation in three isolated septic tanks. E. W. Lehmann. Illinois Sta. Rpt. 1929, pp. 108, 189-208.
Disposal of farm sewage. G. O. Hill. Purdue Agr. Extension Bul. 165 (1929).
Sewage disposal for the farm home. R. C. Kelleher and E. W. Lehmann. Illinois Sta. Cir. 336 (1929).

Sanitation in poultry and livestock shelters and its effect on their products

Air requirements of poultry. Iowa Sta. Rpt. 1928, pp. 24-26.
Ventilation of poultry houses. South Dakota Sta. Rpt. 1929, pp. 10, 28.
Mechanical ventilation for dairy barns. Iowa Sta. Rpt. 1930, pp. 9-11.
Natural draft dairy stable ventilation, H. W. Riley. Agricultural Engineering, 10 (1929), No. 4, pp. 125-127. Contribution from New York (Cornell) Experiment Station.
Effect of artificial heat and insulation upon temperature, relative humidity, and air movements in poultry houses. Indiana Station Report, 1928, pp. 25-28.
Relation of temperature to poultry house design. California Sta. Rpt. 1929, pp. 48-51.
Barn ventilating investigations. New York (Cornell) Sta. Rpt. 1929, pp. 64, 65.
Air requirements for poultry. Iowa Sta. Rpt. 1929, pp. 25, 26, 31, 32.
Ventilation of poultry houses for laying and breeding hens. J. C. Huttar, F. L. Fairbanks, and H. E. Botsford. New York (Cornell) Sta. Bul. 558 (1933).
Barn ventilation with electric fans. A. W. Clyde. Agricultural Engineering, 12 (1931), No. 1, pp. 9-14. Contribution from Iowa Experiment Station.
Ventilation of the Cornell open front poultry house. F. L. Fairbanks and H. E. Botsford. New York Agr. College (Cornell) Extension Bul. 197 (1930).
Ventilation of farm barns. M.A.R. Kelley. U. S. Dept. Agr. Technical Bul. 187 (1930).
Ventilation requirements for poultry laying houses. New Jersey Stas. Report, 1931, p. 14.
Dairy stable ventilation. F. L. Fairbanks and A. M. Goodman. New York (Cornell) Sta. Rpt. 1932, pp. 89, 90.
Electric dairy stable ventilation. F. L. Fairbanks. Agricultural Engineering, 12 (1931), No. 12, pp. 433-445. Contribution from New York (Cornell) Experiment Station.
Study of temperature and humidity in poultry houses. Indiana Sta. Rpt. 1932, p. 14.
A study of temperatures in dairy stables. M.A.R. Kelley. Agricultural Engineering, 14 (1933), No. 2, pp. 47-49. Contribution from U.S.D.A. Bureau of Agricultural Engineering.

Engineering features of sanitary milk production other than animal health

Water cooling of milk and cream. Arkansas Sta. Bul. 280 (1932), p. 35.
Cream refrigeration on the farm and the quality of butter manufactured. F. E. Price, C. J. Hurd, and G. H. Wilster. Oregon Sta. Bul. 305 (1932).
Milk cooling equipment. New York (Cornell) Sta. Rpt. 1932, p. 90.
A study of methods of cleaning milking machines. E. H. Parfitt. Indiana Sta. Bul. 348 (1931).
Cooling of milk. Idaho Sta. Bul. 179 (1931), p. 28.
Dairy equipment sterilization. R. L. Perry. California Sta. Rpt. 1930, pp. 47-49.
A study of methods used in washing and sterilizing of milking machines and their comparative value. Indiana Sta. Rpt. 1930, pp. 30-34.
Preliminary studies of churn sanitation. H. B. Morrison, H. Macy, and W. B. Combs. Jour. Dairy Science, 14 (1931). Contribution from Minnesota Experiment Station.
Cooling milk on Nebraska farms. P. A. Downs and E. B. Lewis. Nebraska Sta. Bul. 266 (1932), p. 31.
Milk cooling on California dairy farms. B. D. Moses and J. R. Tavernetti. California Sta. Bul. 495 (1930).
Cooling as a factor in sanitary milk production, A. C. Dahlberg. Agricultural Engineering, 11 (1930), No. 12, pp. 409-412. Contribution from New York (Geneva) Experiment Station.
The production of high quality milk. I. Cooling—the electric brine cooler with cold air storage versus ice and water. H. B. Ellenberger. Vermont Sta. Bul. 300 (1929).
The application of steam for heating and sterilizing dairy equipment. A. W. Farrall. Jour. Dairy Science 12 (1929), No. 2, pp. 95-113. Contribution from California Experiment Station.
Cream and milk refrigeration experiments, F. E. Price. Agricultural Engineering, 11 (1930), No. 1, pp. 33-37. Contribution from Oregon Experiment Station.
Sterilization of dairy farm utensils with dry heat. A. C. Dahlberg and J. C. Marquardt. New York State Sta. Bul. 612 (1932).
Sterilization of dairy utensils with humidified hot air. A. W. Farrall and W. M. Regan. California Sta. Bul. 468 (1929).
The continuous can washer for dairy plants. A. W. Farrall. California Sta. Bul. 466 (1929).

RESEARCH IN RURAL SANITATION
ACTIVE AT STATE AGRICULTURAL EXPERIMENT STATIONS

Water supply

Farm water systems (Colorado)
Investigation of hydraulic rams (Minnesota)
Stream pollution (New Jersey)
Water supplies (New Jersey)

Sewage disposal

Rural sanitation (California)
Sewage disposal for farm and isolated homes (Illinois)

Treatment of milk product wastes. Studies of sanitary disposal including use of biological filters, aeration, and the like (Michigan)
Farm sewage disposal (Minnesota)
Sewage disposal (Montana)
Biology of sewage disposal (New Jersey)

Ventilation

A study of ventilation and lighting of dairy barns (Idaho)
Mechanical ventilation for dairy barns. Deals especially with fan systems (Iowa)
Farm building ventilation (Minnesota)
Heating and ventilating of homes (Minnesota)
Effect of temperature and humidity on milk production of dairy cows (New Jersey)
Ventilation requirements for poultry laying houses (New Jersey)
Ventilation. Outtake flue construction (New York Cornell)
Proper standards of ventilation (New York Cornell)
Poultry house ventilation (New York Cornell)
Investigations on the relation of stable air conditions to milk production. Includes studies of the effect of sudden changes in stable temperature on the production of milk and fat by dairy cows and the optimum stable air conditions for maximum production consistent with the health and comfort of the animal (Wisconsin)
Temperature control of poultry houses and relation to health and productiveness of laying hens (California)
How to protect poultry from cold. Includes study of housing (Wyoming)
Poultry housing, insulation, ventilation, and artificial heating studies (Indiana)
Air requirements of poultry. Studies to determine basic requirements of poultry house design (Iowa)
Poultry house ventilation and construction. Studying effect of insulation, closing at night during winter, artificial heating, commercial ventilators, and exhaust fans on egg production (Nebraska)
Dairy refrigeration (California) (See below)
Artificial heat in poultry houses. Includes studies of hot water and electric heat (Michigan)

Electric dairy equipment

Dairy refrigeration (California)
A study of the cost of cooling milk by electrical refrigeration on farms. Includes experiments with cooling tanks of wet storage type (Connecticut)
Milk cooling with electric refrigerators (Indiana)
The value of mechanical refrigeration on the dairy farm (Indiana)
Sterilization of milk by electric processes (Maryland)
Electric dairy utensil sterilizers (Maryland)
The comparative efficiency of electrically operated tanks versus ice in the cooling of milk (Massachusetts)
Dairy and creamery sanitation in relation to products. Includes studies of effect of electricity on milk (Michigan)
Milk treatment with electricity (Michigan)
Electric refrigeration for farm dairies (Missouri)
Precooling of milk. To determine (1) quantities and temperatures of water, brine, or both required to be circulated per gallon of milk for cooling, (2) power and labor costs and machine requirements for greatest efficiency, (3) limits of use of improved methods of precooling by farm water supplies, and (4) the availability of electric equipment (New Hampshire)
Dairy refrigeration studies. Comparison of ice with mechanical refrigeration (North Carolina)
A comparison of different methods of cooling milk and cream from the standpoint of the quality and bacterial count of the products (Oregon)
A study of electrically heated milk utensil sterilizers (Pennsylvania)
Electrical refrigeration requirements for Pennsylvania dairy farms (Pennsylvania)
Irradiation of cow's udders and flanks, and of feeds, with ultra-violet light. Effect on production of milk, butterfat, and total solids (Washington)
Electricity on the dairy farm (Washington)
Water heating for dairy cows (Washington)

A Strong Gothic Roof Construction

By L. J. Smith[1]

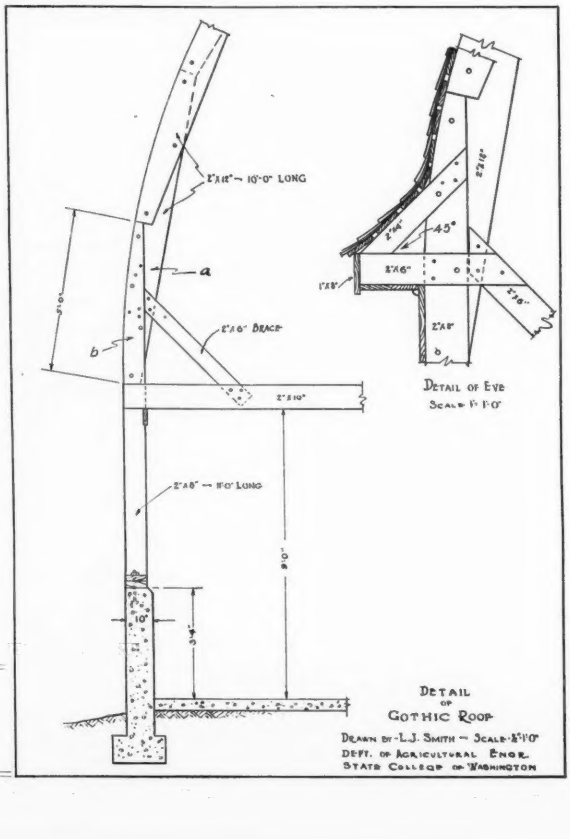
SEVERAL inquiries have come to me in regard to a stronger type of gothic roof construction, which would indicate that the common practice is not altogether satisfactory. Some of the gothic roofs are spreading at the plate line along the center of the side walls.

The accompanying sketch is an attempt to strengthen this type of roof. The first departure from the common practice that will be noted, is that there is no plate. The rafters are made up of two-by-ten or two-by-twelve pieces 10 ft long. The lower end of the first piece rests directly and firmly upon the end of the two-by-ten joist where it is spiked to the studding, which is in this case a two-by-eight for a barn 40 ft wide. The upper ends of the studding above the loft floor line are curved the same radius as the roof, two-thirds the width of the building.

The rafter is built up on the loft floor, and is then swung into position with the lower piece "a" resting against the upper half of the stud "b". The holes in the studding are bored for the bolts and after the bent is in place, the holes in "a" are bored, and four ⅜-in bolts are screwed tightly in place with ample washers.

This construction carries the side stresses of the roof clear down to where the sill is firmly bolted to the concrete foundation. A short two-by-six diagonal brace every six feet bolted to the floor joist, helps strengthen the job. The detail shows the two-by-six lookout and cornice finish. The two-by-six horizontal piece is bolted to the two-by-six brace. There will be a slight curve to the side wall just under the eves, but it will scarcely be noticed.

It is believed that this new type of construction will add greatly to the strength and durability of the gothic roof, which many prefer because of its large loft space.



At the right is shown in detail the improvement in Gothic roof construction designed by L. J. Smith

[1]Professor of agricultural engineering, State College of Washington. Mem. A.S.A.E.

A Study of Dairy Corral Surfacings[1]

By J. D. Long[2]

IN THE work at the California Agricultural Experiment Station with the state dairy inspectors' association, interest has been aroused in the hard surfacing of dairy corrals and lanes. Graveling these areas has been a standard practice in many of the interior valley areas, but even heavy applications were found to have a short life under ordinary drainage conditions.

Hard surfacing appears to present definite sanitary advantages in escaping the muddy corral hazard, in requiring less washing before milking, and in keeping a cleaner barn. Also, there is the health of the animals to consider. No one who has visited some of the valley dairies during the rainy season and viewed the mucky morass into which the animals sink up to their bodies, can escape the belief that here lie excellent conditions for the dissemination of disease through the herd. Hillside dairies with good drainage have less severe conditions, but even here a limited area of hard surfacing in corrals and lanes appears feasible. The possible saving of manure value, it must be admitted, does not appear a factor of much interest to the California dairyman.

The California College of Agriculture series of standard dairy building plans is centered about a milking barn which is used only at milking periods. Between times the animals are to be sheltered and fed roughages in an adjacent structure. This usually consists of open sheds around a central hay storage, or with hay storage close by, similar to the "covered barnyards" of the eastern states. Surfacing is recommended for the lane leading to the milking barn and for small corrals along the open sheds to be used during inclement weather. The corral area is more or less arbitrarily set at 50 to 75 sq ft per cow, in addition to the 40 sq ft under the shed.

Three types of materials have been used for surfacings—wood, portland cement concrete, and asphaltic mixes of various kinds.

Wood Plank. The wood plank corrals have been used mostly in the north coast counties—the center of the redwood lumber industry, and an area with high annual precipitation, reaching 100 in in one county. The corrals are raised 1 to 6 ft above the ground and are used on dairies in the marshy valley bottoms, and on hillsides as well. For these local conditions they appear a very successful solution of the problem.

A few plank corrals have been laid in the interior valleys. Those laid on the surface of the ground, especially if the planks are not fastened to sleepers, have proved of doubtful sanitary value because of the filth accumulating beneath the planks and oozing up through the cracks. No serviceable life data is yet available for these structures.

Portland Cement Concrete. Portland cement conrete has been given a general recommendation for a number of years on the theory that "mixing a little cement with the gravel layer is more economical than hauling in gravel year after year." The California station standard specification calls for a 4-in slab of 6½:1 water-cement ratio. This is probably overdesigned, since slabs 2½ in thick and of leaner mixes appear to be durable under ordinary manure and hay wagon loads. Attention to securing a well-compacted subgrade, definite drainage slopes, and satisfactory disposal of surface drainage is essential.

Attention has been attracted recently to the possibility of economies in using a cement-bound macadam of large aggregate, similar to the old "Hassam" type road surfacings which have been resurrected to popular favor for secondary roads during the past two years. Using 1 to 1½ in rock in slabs twice that thickness and compacting with a 300-lb hand roller would appear to make concrete work with hand equipment feasible and economical. This method is deserving of tests.

Asphaltic Surfacings. Interest was early aroused in asphaltic surfacings because of possible advantages over portland cement concrete, that is, greater resilience, a lower heat conduction rate, and the lower cost of certain types. These advantages have not been definitely proved, but are believed in general to be true.

Asphaltic road oils premixed with aggregate or sprayed on a well-graveled surface have not been considered as deserving of trial for the character of traffic experienced in corrals. They serve admirably under rolling road traffic, but appear to disintegrate under "punching." It might be mentioned here that corral and shed surfacing does not have loads concentrated as they are in the milking barn. Experiments in the latter structure with asphaltic concrete over a worn portland cement concrete bore out the results secured some years ago at the Iowa station—the asphalt layer failed by flowing out from under the feet of the animals, particularly along the manger curb.

Asphalt pavement contractors interviewed relative to corral surfacings have expressed the view that hot-asphalt-bound macadam would prove satisfactory for corral service if the proper grade of asphalt were used —E grade, 90-point penetration being suggested. This method could be readily handled by hand labor, the only special equipment needed being a 300-lb hand roller, a heating kettle, and hand-pouring pots or pressure sprayer.

The contractors were more favorable to a 4-in asphaltic concrete laid hot as on roadways. This they guaranteed to be satisfactory. The cost range was not unfavorable, about 12 cents per square foot, but it was limited to use within a short trucking radius of the central plant.

Our experimental work to date has been limited to the use of asphaltic emulsions and cut-back asphaltic concretes.

Asphaltic Emulsions. Bituminous-aqueous emulsions were first tried for corral surfacing at the California station in 1926. A product known commercially as "Lay-Kold," which was reported to have a clay as the "protective colloid," was used. The material was dipped from the barrels and mixed with creek-run gravel in a concrete mixer. It was spread along a feed rack under an open shed in a 2-in thickness, and in spite of poor workmanship, due to the antagonism of the laborers, the main part of the surfacing has stood successfully under light usage. A failure occurred in six years use in one area, a shallow gutter in which liquid manure accumulated.

Similar asphaltic emulsions are now being advocated for cold penetration macadams on secondary highways, and would seem to be suitable by this method for corrals. They have the advantage of being hand-tool, low-cost applications.

"Cut-Back" Asphaltic Concrete. "Cut-back" asphalts are composed of a base of great adhesiveness combined with a suitable proportion of volatile ingredients (kerosene or distillates), intended to evap-

[1]Paper presented at a session of the Structures Division of the American Society of Agricultural Engineers during the 27th annual meeting of the Society held at Purdue University Lafayette, Indiana, June 1933.

[2]Assistant professor of agricultural engineering, University of California. Mem. A.S.A.E.

orate within a short time after the binder is applied. The material tried in this test was mixed hot at the plant, trucked approximately 65 miles, and piled on the ground for a maximum of three days before being used. A resume of the project follows:

1 Subgrade leveled Monday, Tuesday, and Wednesday morning. 2200 sq ft, 4½ man-days labor.

2 Material trucked in Monday and Tuesday.

3 The material was spread 2¾ in thick and rolled twice Wednesday afternoon, using a 3-ton tandem gas roller. The slab compacted to about 2 in. The interior of the stock pile was found warm and friable; the outer edges had solidified but could be broken apart. After spreading in place, the material turned grayish as the solvent evaporated. The first rolling was given one to two hours after spreading, water being used on the rollers to keep the material from picking up. The second rolling was given an hour after the first.

4 On Thursday morning the entire area was given a "dust coat" of ⅛ in to dust cut-back asphalt mix and rolled immediately. The edges were painted with asphalt-aqueous emulsion and built up with screenings. Cows were turned onto the slab Thursday afternoon.

5. Moving the material from the stock pile and spreading required 4½ man-days, hand tamping around obstructions and finishing the edges ¾ man-day, and rolling about 1 man-day net.

Subgrade Specifications. Manure and loose materials were cleaned out to a firm, graveled base. Holes were filled with clay and rock tamped in place, and the entire base rolled, then covered with rock screenings (⅛ in to dust) laid ¼ to ½ in thick and rolled again.

Cut-back asphaltic concrete, closed base, mixed at 180 deg F.

Asphalt—85 lb of 95+ per cent, 80-penetration asphalt to the 150 lb batch. Twenty per cent of kerosene "cut-back" solvent used.

Aggregate—45 per cent—¼ to 1 in maximum size
15 per cent—⅛ to ¼ in
40 per cent—dust to ⅛ in.

Cost

One ton of material, covering 80 sq ft compacted to 2-in thickness, was quoted at $4.25 delivered. The manufacturer offered a contract figure of 7 cents per square foot for a similar 2-in pavement laid over a firm subbase prepared by the owner.

Results

The first few days of use the surface showed slight hoof cutting and wagon-wheel marks. At the end of the first year an area of about one square yard cracked in such a way as to indicate a subgrade failure due to moisture. The remainder of the surface was in very good condition. This condition has been maintained during the second year. Some unevenness of surface has developed due to the traffic of the animals, and occasional hoof marks are apparent. One small section along the manger in a part subjected to very light use showed signs of incipient failure along the front hoof line in the first two weeks, but has not developed noticeably since. Areas adjacent to the watering cups and water trough are sound.

As a result of the success of this trial during its first three months, a local dairyman contracted on a 90-day, deferred-payment basis for approximately 12,000 sq ft of surfacing. The contractor changed the specifications as follows:

Subgrade—Two inches of road rock (60 per cent rock dust, 40 per cent rock to ¾ in), water and roll.

Base course—One and one-half inch layer (15 lb per sq ft) open-type asphaltic concrete, with aggregate ranging from ¼ to 1 in, and 1.9 per cent by weight of E grade cut back asphalt. Roll.

Finish course—One-eighth inch layer of fines coated with cut-back, E grade asphalt. Roll.

Seal coat—Pressure spray coat, ¼ to ½ gal per sq yd of emulsified asphalt coated immediately with 12 lb per sq yd of ⅛ to ¼ in crushed rock screenings. Roll.

The pavement was cured for two weeks before being used by animals but had definitely failed within 10 days thereafter. An examination six months later showed that the asphalt layer measured but 1¼-in thick and was consolidated for but half its depth. The rock fill subgrade appeared loose and yielding. Large holes, 6 and 8 ft in diameter, had been punched through the surfacing and 6-in into the subgrade, and the remainder of the surface was very uneven.

Summary

1. Hard-surfaced dairy corrals deserve consideration from the standpoint of sanitation, disease control, reduced cleaning labor, and manure saving.

2. An area of 50 to 75 sq ft of surfaced corral per animal is recommended.

3. Wood plank is particularly adapted for hillside construction.

4. Portland cement concrete surfacings properly designed and laid are generally considered successful. Possible economies may result from the use of cement mortar macadam, of the "Hassam" pavement type.

5. Asphaltic surfacings may possess advantages of a lower heat conductivity rate, greater resilience, and lower cost. Certain types seem especially well adapted to the economical use of farm labor and hand tools. A safe design for all types has not yet been determined.

6. Due to the ductility of certain types of asphaltic surfacings it is recommended that when they are used portland cement concrete slabs be laid in areas subjected to concentrated traffic, as along mangers and in doorways.

7. A firm base protected from underseepage is important to portland cement and asphaltic concrete slabs, and thermal expansion joints necessary for the former.

8. Positive surface drainage is essential to the success of any surfacing.

Still Opportunity for Engineers

THE engineer has been a highly important member of the community even before the records of written history. His was the inquiring mind that turned his discoveries into practical appliances for the common good. He investigated fire and learned to kindle it; he studied the rolling log and invented the wheel; he studied metallurgy and produced the iron age; he brought potable water to the villages and made them cities; his studies in statics made possible palaces and cathedrals. Watt's steam engine restored England's coal resources; and our steamships and railways opened up this country to development. Threats of depressions have given way to new industries developed by the engineer; and in this country's history, recovery from depression periods have always been accompanied by new industries whose developments were begun by the engineer before depression began. Even today we find startling developments in railroads and street railways that threaten to revolutionize transportation on land. Probably 50 per cent of our factories have out-of-date equipment, and many processes have been completely altered. Is it too much to believe that the same type of creative engineering mind is still with us and, given the opportunity and encouragement, will create new industries which will absorb the present unemployment and the ever-increasing supply of wage earners due to growth of population and improvement in agricultural methods?

The engineer alone cannot restore prosperity or prevent depressions, but he can make his voice heard and understood if he will remember that he is only one per cent talking to 99. . . . . He must learn to speak in a language that the 99 per cent will understand.—W. A. Shoudy in "Mechanical Engineering" for December 1933, page 725.

Problems in the Design of Structures for Controlling Groundwater[1]

By Doris Farr[2] and Willard Gardner[3]

THIS paper is presented from the point of view of the physicist. Consistent units and homogeneous equations are used in order to avoid difficulties incident to the use of artificial units and special empirical equations. Various articles of this nature have been presented from this laboratory. Particular reference is made to the paper, entitled "Computing the Effective Diameter of a Well Battery by Means of Darcy's Law," by Eliason and Gardner[4]. Although the analysis is based necessarily upon an ideal set-up of conditions, the conclusions are far-reaching and offer promise of increase in the efficiency of well structures.

On the basis of available cost data for materials of construction, it appears that well batteries of large diameter may be built cheaper than the small wells used at present in the West. For example, assuming a cost of $1.00 per foot for a 4-in pipe, a well battery of six wells 70 ft in depth, and having an effective diameter of 24 ft, could be built for less than $1,000.00. It appears, furthermore, that the cost is a linear function of the effective diameter, and, as will be shown later, this fact has an important bearing upon the problem of design.

Darcy's Law. As originally announced, Darcy's law states that the velocity of flow of a liquid through a horizontal column of porous material varies directly with the pressure head difference and inversely with the length of the column. It may be expressed algebraically as

$$V = K(p/h) \qquad [1]$$

where V is the velocity of the liquid, p is the difference in pressure head at the ends of the column, h is the length of the column, and K is a constant, the value of which is dependent upon the viscosity of the liquid and upon the nature of the soil. In this form the equation has limited usefulness, whereas in the form of a differential equation it has general application.

For the special case of flow toward an axis, as in the case of a tile drain, the differential equation has the simple form

$$v = k(d\Phi/dr) \qquad [2]$$

where r is the distance from the axis toward which the water flows, v is the so-called macroscopic velocity, or the velocity averaged over soil grains and pores, and Φ is the potential function. This function is made up of two terms, thus

$$\Phi = p/\rho + \phi \qquad [3]$$

where p is the pressure, ρ is the density of the liquid, and ϕ is the gravitational potential. This potential has the dimensions of velocity squared. The simple expedient of dividing Equation 3 through by g, the acceleration of gravity, reduces the terms to quantities of the dimension of length. The potential is thus expressed as a length and the designation *head* seems to convey more meaning to engineers. It is important to observe, however, that Equation 2 and similar equations must be kept homogeneous by a proper adjustment of the constants.

It may be pointed out parenthetically that the force per unit mass as a vector point function may be obtained for a perfect fluid by computing the negative gradient of the potential as defined by Equation 3. The shearing stresses which arise in the case of a *physical fluid* in motion are presumed, on the basis of Darcy's law, to be directly proportional to the velocity, the acceleration being presumed negligible. Equation 2 is therefore a special case of the somewhat more general form,

$$v = k\nabla\Phi \, {}^{*} \qquad [2']$$

Exhaustive experimental data indicate that this law does not hold rigorously for high-potential gradients, but that it serves as a good first approximation for most practical purposes. Its introduction as an approximation is equivalent to assuming that the velocity of groundwater as a vector point function has a potential, which simplifies the solution of problems in this field.

Horizontal Drains. It follows as a direct consequence of this law that, where there is an appreciable pressure near the surface, the installation of tile drains, for effective lowering of the water table is an expensive procedure. This will be shown in the analysis to follow.

At times when the weather is damp and foggy, the water table tends to rise to maximum heights and careful design should take proper account of this fact. In order to provide adequate protection under these conditions, drains should be installed at sufficient depth and sufficiently close together to reduce the pressure to zero (or to atmospheric pressure) midway between the drains at the surface of the ground. The methods of hydrodynamics are of particular value in aiding to determine these magnitudes. The curves of Fig. 1 have been drawn to represent the stream lines resulting from the combination of drains with a uniform flow vertically upward, and the algebraic development will make clear the basis for the figures presented in the table. Two conditions will be satisfied by the equations: (1) The total flow upward from the gravel, computed for the one unit of width s and length l on the assumption that the available head H is utilized in determining a uniform vertical flow, will be equated to the aggregate flow into a single drain, computed on the assumption that the flow is inward along the radial lines drawn from the axis of the drain. (2) The resultant pressure will be zero (or atmospheric) midway between drains at the surface of the ground and at the circumference of the drain.

In order to avoid unnecessary mathematical difficulties, however, it will be assumed that the soil extends to great distances above and below the level of the drains. The diagram will illustrate with sufficient precision the error thus committed. The flow through

[1]Contribution from the Department of Physics, Utah Agricultural Experiment Station. Publication authorized by the Director, September 7, 1933. Released for first publication in AGRICULTURAL ENGINEERING.

[2]Graduate student, Utah State Agricultural College.

[3]Physicist, Utah Agricultural Experiment Station.

[4]Orville L. Eliason and Willard Gardner. Computing the Effective Diameter of a Well Battery by Means of Darcy's Law. AGRICULTURAL ENGINEERING, vol 14 (1933), no 2, pp 53-54.

*With the equation in this form, **k** is negative.

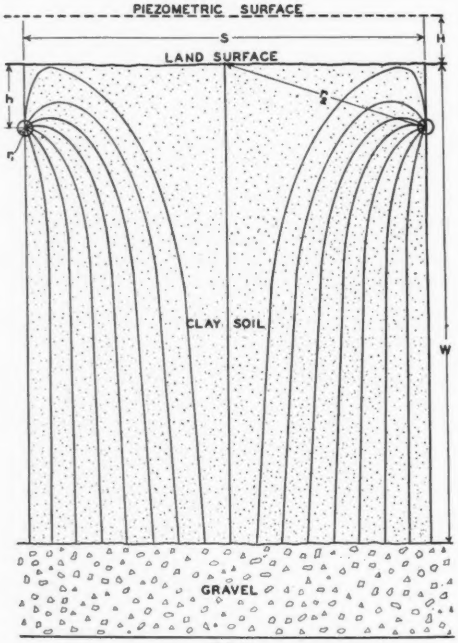


FIG. I

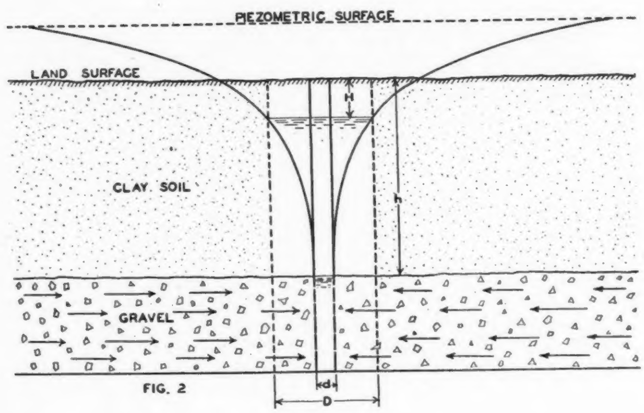


FIG. 2

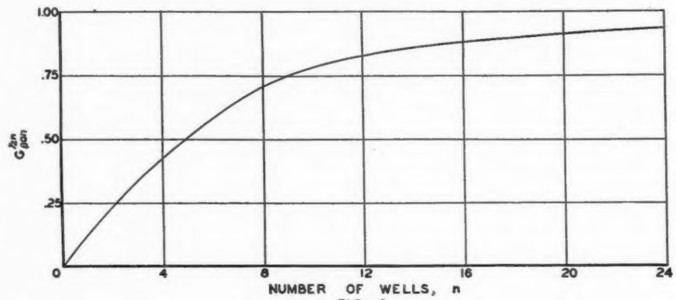


FIG. 3

the two central "tubes" will reach the surface of the ground to be evaporated rather than to be diverted into the drains. This will lead to a magnitude for the drain spacing slightly large and on that account an inequality sign will be used in the final formula resulting from the analysis.

The equation of continuity for the flow into the drain may be written

$$Q = 2\pi rl\rho v \qquad [4]$$

where Q is the mass[5] of water flowing upward from the selected area per unit of time and ρ is the density of the water. The elimination of v from this equation by means of Equation 2 will lead to the simple differential equation

$$Q = 2\pi rl\rho k(d\Phi_s/dr) \qquad [5]$$

the subscript s being introduced in order to emphasize that the potential Φ_s is that part of the final total potential Φ which is due to the presence of the drain regarded as a sink independently of the uniform flow.

The corresponding equation for the uniform vertical flow from the gravel may be written

$$Q = sl\rho k(Hg/w) \qquad [6]$$

with a uniform drop in potential along the vertical lines of flow. In this equation H represents the available head, g the acceleration due to gravity, and w the depth of soil overlying the gravel.

By means of this equation Q may be eliminated from the differential equation (Equation 5), and it is readily integrated, giving after substituting appropriate limits

$$\Phi_{s2} - \Phi_{s1} = \{(sHg/w)/(2\pi)\}\ (ln\ r_2/r_1)^{**} \qquad [7]$$

r_2 being the distance from the axis of the drain to the point midway between drains at the surface of the ground and r_1, the radius of the drain. The aggregate potential at a point due to various sources is the algebraic sum of the separate potentials. If, therefore, we add to the terms Φ_{s2} and Φ_{s1} the respective contributions due to the uniform vertical flow, it is evident that these contributions will differ by an amount equal to $(h/w)(Hg)$, inasmuch as Hg represents the total potential drop from the upper boundary of the gravel along the vertical streamline midway between drains to the surface of the ground. The difference in total potential, therefore, at the drain and at the surface of the ground midway between drains will be $-(h/w)(Hg)$ more than the difference indicated in Equation 7. Adding this quantity, therefore, to the right-hand member of Equation 7, and then introducing the second of the two conditions mentioned in a previous paragraph, the following equation results

$$-(h/w)(Hg) + \{(sHg/w)/(2\pi)\}\ (ln\ r_2/r_1) = hg \qquad [8]$$

inasmuch as the pressure is to be zero at both places and the potential difference will be due entirely to difference in elevation of the drain and the surface of the ground.

If we now introduce the approximation of equating $s/2$ to r_2 and also the inequality sign for the reason explained, the final formula becomes

$$s < (2\pi wh)(1 + H/w)/(H\ ln\ s/2r_1) \qquad [9]$$

H and w are quantities determined by the field conditions, h represents the arbitrary depth of the drain, and r_1 the arbitrary radius of the tile. The accompanying table of computed values of s for various values of

[5]It seems advantageous under certain conditions to keep foremost in mind the flux and flux density, writing **Q** equal to the product of the area and flux density **ev** rather than to the product of the area and the velocity **v**.

The symbol **ln is used in this equation to indicate the natural logarithm.

the other quantities has been prepared in order to illustrate the meaning of the inequality. It will be seen, for example, that for an excessive value of h ($h = 10$ ft), an excessive value of r_1 ($r_1 = 1$ ft), and a comparatively small value of H ($H = 5$ ft), w taken as 50 ft, the drain spacing should not exceed 158 ft. Where $h = 3$ ft, $r_1 = \frac{1}{4}$ ft, $H = 30$ ft, and $w = 50$ ft, the drain spacing should not exceed 15 ft.

Table of Computed Values of s

h	r_1	H	w	s
3	¼	5	50	46
3	¼	30	50	15
10	¼	5	50	125
10	¼	30	50	39
3	1	5	50	61
3	1	30	50	21
10	1	5	50	158
10	1	30	50	52

(Distances expressed in feet).

For many practical cases, therefore, the drain spacing is so close as to make the cost of effective drainage by means of tile drains prohibitive.

Vertical Wells. On the other hand, provided wells be designed to reduce power costs sufficiently, pumping offers promise for effective drainage. It is important to observe, as has been pointed out by Gardner, Israelsen, and McLaughlin[6], that for the hypothetical case of a uniform stratum of artesian gravel of piezometric surface is a logarithmic function of the distance from the axis of the well. This fact has an important bearing upon the design of the well.

Increasing the diameter of the well decreases the necessary height of lift as will be seen by Fig. 2. For example, if the well whose diameter is represented by d were so enlarged as to have a diameter D, the height of lift would be reduced from h to H. The problem of determining the appropriate size resolves itself into a balancing of the saving in power costs against the cost of enlarging the well. The cost of the pump and pump equipment also will enter into the problem. By reducing the flow from a single well the height of lift could be reduced, but this would require more wells and more pumps to handle a given amount of water. The well battery is a device for reducing the flow from an individual small well and using a single pump to operate a series of such small wells.

It is possible to design various kinds of well batteries, but there appears to be some intuitive justification for arraying the small wells on a circle. The problem of choosing the appropriate number of small wells presents itself, but no rational method for determining this number has been devised. Fig. 3, drawn from the equation of Eliason and Gardner, is helpful and indicates that the choice should lie somewhere between four and ten. The quantity $(G^{\beta_{on}})^{1/2n}$ is a factor, which when multiplied by the radius of the circle in which the small wells are located, gives the effective radius of the well battery. No attempt is made to choose the proper size of pipe. Inasmuch as the friction loss varies inversely with the square of the diameter, the size should probably be no less than 3 to 6 in in diameter as a general rule. The authors, however, are not committed to any choice for the number of wells or the size of pipe.

Pumping Costs. As previously mentioned, the cost of such a well battery is a linear function of its effective diameter, while for large excavated single wells the cost involves an important term containing at least the square of the diameter. It is presumed that in the aggregate for large scale pumping the cost of power will be approximately a linear function of the amount consumed.

The capital cost of a well plant will therefore be treated as a linear function of the effective radius of the well and the product of the height of lift H and the quantity of water Q pumped per unit of time. A term $b'Q$ is introduced to take account of costs proportional to Q. If the product of Q and the time factor representing interest and depreciation be divided out[7], the result represents the cost z per unit of flow per unit of time, and the design should be controlled primarily by this factor where pumping operations are conducted on a large scale. The equation may be written

$$z = \frac{a + cR_e}{Q} + PH + b \quad [10]$$

where the constants have the following significance:

a is the aggregation of well costs assumed to be independent of R_e and H, such, for example, as the cost of transformer, pump, and the vertical pipes for the small wells. It has the "economic" dimensions of capital multiplied by a factor (of the dimensions of reciprocal of time) representing interest and depreciation rate. It will be unnecessary for the purpose of this article to assign an order of magnitude to this factor.

c is a constant of proportionality, of order of magnitude 4×10^{-9} dollars per second per centimeter for the case of six wells in the battery, the cost of pipe approximating $1.00 per foot, interest and depreciation taken as about 40 per cent per year. This extremely high rate is selected in order to introduce safety into conclusions to be drawn.

P is determined by the power cost. Its dimensions differ from those of z by a factor having the dimensions of reciprocal of length. It has an order of magnitude of 10^{-12} dollars per centimeter per gram when the power charge is two cents per kilowatt-hour and the motor has an efficiency of 50 per cent.

b is a constant having the same dimensions as z, and representing terms in well costs that are proportional to Q. It is unnecessary here also to assign an order of magnitude.

For the case of a single well in a large area the quantity of water Q is determined by R_e and H, and, if it be regarded as constant, these two variables will no longer be independent, and it becomes possible to determine the derivative of H with respect to R_e corresponding to the minimum value of z, thus

$$dz/dR_e = c/Q + P(dH/dR_e) = 0 \quad [11]$$

from which we obtain

$$dH/dR_e = -c/(QP) \quad [11']$$

On the basis of Darcy's law, it has been shown[6] that

$$Q = CH/(\ln R/R_e) \quad [12]$$

where C is defined by the following equation

$$C = 2\pi\rho l k g$$

In this equation, ρ is the density of water, l is the thickness of the water-bearing stratum, k is the transmission constant of the water-bearing gravel, and g is the acceleration of gravity. The magnitude R in Equation 12 is the horizontal distance from the axis of the well to the curve of intersection of the piezometric surface[8] with the surface of the ground (assumed horizontal). If this is regarded as constant, with Q also constant, Equation 12 shows the corresponding relation between

[6]Willard Gardner, O. W. Israelsen, W. W. McLaughlin, The Drainage of Land Overlying Artesian Basins. **Soil Science**, vol 26 (1928), pp 33-45.

[7]The constants **a**, **c**, **P**, and **b** of Equation 10 include implicitly this interest factor, and therefore **Q** appears alone in the denominator, and the constant b' does not enter the equation.

[8]Reference is here made to the cone-shaped surface representing the piezometric surface with the pump in operation.

R_e and H. Differentiating this equation with Q and R constant leads to

$$dH/dR_e = -Q/(CR_e) \qquad [13]$$

Careful study of the conditions imposed in performing the differentiation reveals the fact that this is the same derivative as that shown in Equation 11'. Equating the right-hand members therefore of Equations 11' and 13 shows that, for maximum efficiency,

$$R_e = Q^2P/(cC) \qquad [14]$$

To illustrate, if Q is taken as 225 gpm (which reduces to 14,200 cu cm per second), the magnitudes introduced for the constants P and c, together with a magnitude of 200 cgs units for C, will lead to a value of 250 cm (approximately 8 ft) for R_e. It should be emphasized, however, that the choice of 225 gpm is wholly arbitrary and was chosen for the reason that it represents a comparatively small well. Choosing a large value leads to a large value for the economic radius, and this analysis leads qualitatively only therefore to the conclusion that the well should be large.

Where a single well is located in a large artesian region, it should not be regarded extravagant to assume that Q is proportional to R_e. If it may be permitted, therefore, to assume as a first approximation that the quantity of water available from a well at a definite drawdown is proportional to the radius of the well, we may introduce the following equation

$$Q = pR_e \qquad [15]$$

where p is written for a proportionality constant. By means of this equation we may eliminate Q from Equation 10, leading to

$$z = \frac{a + cR_e}{pR_e} + PH + b \qquad [16]$$

From the form of this equation it is obvious that z will continue indefinitely to decrease with increasing R_e with H maintained constant, and this conclusion is independent of the magnitude of the power cost factor P.

The construction of extremely large wells by means of this battery system would require that the water be conveyed long distances through the radial pipes leading to the central pump, and the friction should be taken into account in the completion of the design. It seems evident, however, on the basis of Equation 16 that the practice of constructing large wells for large scale pumping would lead to greater efficiency regardless of the more important feature of decreasing the cost for power.

Conclusions

It seems reasonable to conclude that, under certain conditions where artesian strata lie near the surface, adequate drainage requires such close spacing of drains as to render the cost prohibitive.

It seems reasonable also to conclude that where pumping for drainage is to be adopted, the well battery system offers important advantages over the small wells constructed under present practice in the West.

The analysis seems to point definitely to the conclusion that there is opportunity for improving the efficiency of design of such well structures by specifying large diameters.

The conclusions rest upon an ideal set-up of conditions, but the analysis is thus rendered clear and straight-forward, and the authors believe serious consideration should be given to such procedure.

AUTHORS' NOTE: The authors desire to express appreciation to Dr. O. W. Israelsen and to Mr. Everett H. Larson for valuable suggestions made in connection with the subject of this paper.

Lightning Protection[1]

By S. A. Knisely[2]

THE Code for Protection Against Lightning sponsored by the American Institute of Electrical Engineers and the U. S. Bureau of Standards, and approved by the American Standards Association and the National Fire Protection Association, is the most authoritative document available on the subject of lightning protection. It contains the following clear and concise explanation of the fundamental principles of protection against this hazard:

> The fundamental theory of lightning protection for buildings is to provide a means by which a discharge may enter or leave the earth without passing through a non-conducting part of the structure, as, for example, parts which are made of wood, brick, tile, or concrete. Damage is caused by the heat and mechanical forces generated in such non-conducting portions by the discharge, whereas in metal parts the heat and mechanical forces are of negligible effect if the metal has sufficient cross-sectional area. There is a strong tendency for lightning discharges on structures to travel on those metal parts which extend in the general direction of the discharge. Hence, if metal parts are provided of proper proportions and distribution, damage can be largely prevented. . . . .
>
> The nature of the structure will have a large influence upon the extent of the protection to be considered. Thus an all-metal structure is practically immune to lightning damage because of its construction, and very simple measures usually suffice to make protection complete. Metal-frame buildings with terra cotta or tile facings are next in order as requiring somewhat more extensive measures, while as the amount of metal in the roof and sides of a building decreases, the protective measures required approach more nearly a complete system. Buildings made entirely of non-conducting materials, such as wood, stone, brick, or tile, require complete systems with special attention to contents if they house large metal objects, such as machinery and the like.
>
> The required condition that there be a metallic path for the part of the discharge which is intercepted is met most fully by a grounded metal or metal-covered structure, which presents what might be thought of as an infinite number of parallel conductors from the uppermost part of the structure to the earth.

A surprisingly large number of American farmers still ridicule the use of lightning rods. Sometimes it is because they have seen rodded buildings damaged or destroyed by lightning, without appreciating the fact that a faulty installation was to blame. But science has long since proved that the properly installed lightning rod system is a very effective protection against lightning. Minute instructions are laid down in the Standard Code for safeguarding quality of material and workmanship. Where these specifications are followed in installing a complete lightning rod system or simple grounding devices, the chances of failure are almost nil. Then, too, experience has demonstrated that even a faulty rod installation is better than none at all.

Where buildings are made entirely of non-conducting materials, such as wood, steel, brick or tile, complete lightning rod systems with elevation rods extending above the roof are required.

In the case of buildings which are roofed or roofed and clad with metal of substantial weight, and with all parts thereof in good electrical contact, additional conductors can be dispensed with, due attention being given only to adequately grounding such metal. Air terminals need be provided only on such non-conducting projections extending above the metal roof, as brick chimneys, wood ventilators, etc. Metal ventilators, for illustration, require no air terminals but must be electrically connected to the metal roof. Usually a simple grounding from the metal eaves or metal siding at diagonally opposite corners is all that is required to protect a metal-roofed or metal-clad building of ordinary size.

[1]From a paper presented at a session of Structures Division of the American Society of Agricultural Engineers during the 27th annual meeting of the Society, at Purdue University, Lafayette, Indiana, June 1933.

[2]Director, trade research division, National Association of Flat Rolled Steel Manufacturers. Assoc. Mem. A.S.A.E.

Agricultural Engineering Digest

A review of current literature by R. W. TRULLINGER, senior agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture.

USE OF ALUMINUM IN DAIRY EQUIPMENT, *H. A. Trebler* (Internatl. Assoc. Milk Dealers, Proc., 25 (1932), Plant. Sect., pp. 46-87, figs. 14). This study dealt with the physiological, chemical, physical, and mechanical properties of aluminum when used for dairy equipment.

The conclusion is that aluminum appears to be the cheapest and best material at present available for transportation and storage of milk. Its substitution for present materials will permit from 20 to 50 per cent saving in cost of weight. Aluminum foil insulation compares favorably with cork, both in cost and insulating properties, and will make possible a very important saving in weight for transportation tanks and insulated truck bodies. Aluminum can further be used practically every place where tinned copper or tinned iron are now being used and will be found cheaper and in general much more satisfactory if certain precautions are taken.

Aluminum will prove satisfactory in dairy equipment if (1) contact with other metals is avoided in the liquid and heavy contamination with other metals is avoided in the system previous to the aluminum equipment, (2) silicate is added to cleaners and sterilizers, and chromate to brines, and (3) paper or rubber gaskets are used in connection with aluminum couplings and the couplings tightened by hand only.

The sensitiveness to electrolysis is the chief disadvantage of aluminum. The chief advantage of the metal are nonoxicity, insolubility in dairy products, light weight, low cost, and good workability.

THE VARIOUS FORMS OF ENERGY USED IN THE AGRICULTURE OF THE VICINITY OF BOLOGNA AND THE POSSIBILITY OF AGRICULTURAL ELECTRIFICATION ([trans. title] (Ingegnere, 7 (1933), No. 3, pp. 185-193, figs. 7). A survey of the agricultural utilization of power in the vicinity of Bologna, Italy, indicates that in round figures this amounts to 74,000 hp as used on some 173,000 acres of arable land which might be electrified. The annual cost of power used on this land is about 50 lire ($2.63) per acre. It is estimated that the power operations involved might be done electrically for one fourth of this cost.

An analysis of the present available power indicates that it includes about 40,000 hp in animals, about 19,400 hp in tractors, and about 3,030 hp in electrical equipment. Statistical and economic data on the adaptation of electricity are summarized.

IRRIGATION PRACTICE AND ENGINEERING.—I, USE OF IRRIGATION WATER AND IRRIGATION PRACTICE, *B. A. Etcheverry* and *S. T. Harding* (New York and London: McGraw-Hill Book Co., 1933, vol.1, 2. ed., rev., pp. X+256, figs. 111). This is the second edition, revised, of this text and handbook. It has been completely rewritten, the changes from the first edition being mainly in the examples used to illustrate the principles of farm-irrigation practice.

The treatment of irrigation practice in this edition is limited to the handling and use of water on the farm. Pumping from ground water is included and given special treatment.

OXIDATION OF SOME HYDROCARBONS [trans. title], *Mlle Estradere* (Compt. Rend. Acad. Sci. [Paris], 196 (1933), No. 10, pp. 674-676, fig. 1). Studies are reported on the oxidation of hexane, cyclohexane, and cyclohexene under constant pressure and under conditions conducive to detonation. Mixtures of the hydrocarbons with oxygen (4:1) at atmospheric pressure were subjected to temperatures of from 300 to 600 deg Centigrade.

It was found that the phase of active oxidation began at the point where the oxygen decreased rapidly in the gas at temperatures of 330, 340, and 410 deg, respectively, for hexane, cyclohexane, and cyclohexene. There was a simultaneous appearance of carbon monoxide in important quantities. Peroxides were produced only at temperature intervals of from 10 to 15 deg, the maximum yields being at 330, 340, and 410 deg. At these temperatures quantities of carbon dioxide and aldehydes were also produced. The cyclization of saturated hydrocarbons does not appear greatly to increase their resistance to oxidation.

"DUNLAP" PNEUMATIC TYRES, WHEELS, AND HUBS FOR FARM CARTS ([Gt. Brit.] Min. Agr. and Fisheries, Agr. Mach. Testing Com. Certif. and Rpt. 46 (1933), pp. 7, pl. 1 fig. 1). Tests conducted by the Institute for Research in Agricultural Engineering of the University of Oxford are reported. They related to the comparative draft and pay load of a two-wheeled farm cart using the ordinary iron-tired wheels and wheels fitted with pneumatic rubber tires.

The use of the peumatic rubber-tired wheels was found to reduce the draft of the cart from 13 to 41 per cent according to load carried and type of land traversed. The increase in pay load that could be carried varied from 35 to 108 per cent according to ground conditions. The ground was less cut up by the pneumatic tires than by the iron tires.

TESTS OF ANCHORAGES FOR REINFORCING BARS, *C. J. Posey* (Iowa Univ. Studies Engin. Bul. 3 (1933), pp. 31, figs. 18). The object of this investigation was to secure an anchorage giving high ultimate values of spirally reinforced hooks but without their tendency toward excessive slip.

The specimens were all made of ½ or ⅝-in diameter high-carbon steel bars cast in concrete blocks, which were 9 in square and approximately 2 ft long. A few of the specimens were cast in blocks 6 in wide instead of 9 in. The length was varied an inch or so either way when necessary to allow for differences in the height of the exposed portion of the bar. The proportion of size of bar to the size of the enclosing concrete specimen was chosen as representing closely what is common in reinforced concrete construction.

It was found that the early load-slip ratio is greater the larger the radius of hook. The larger hooks carry greater loads until a slip of three or four hundredths of an inch is reached. At slips greater than three or four hundredths of an inch, the smaller hooks carry greater loads than do the larger hooks. In this range the large hooks lose load as the slip increases, while the small hooks pick up more load. Variability of results increases as the radius of bend increases, being greatest with the straight embedments. None of the hooks (or straight bar) with embedment of 22 diameters total length furnished a satisfactory anchorage in the concrete used. There was too great a variability and the strength was insufficient.

The most satisfactory anchorage tested during the 4 years of investigation was a straight embedment of plain round bar, the surface of which had been roughened by rows of indentations made with a blunt cold chisel. A length of embedment of only 22 times the diameter of the bar consistently developed a bar stress of 20 times the ultimate compressive stress of the concrete, with a slip of less than 0.01 in at the loaded end. These bars were superior to ordinary commercial deformed bars, both in ability to pick up load with little slip, and in ultimate carrying capacity. The essential difference between the roughened bars of these tests and ordinary deformed bars is in the size and frequency of the deformations, those on the commercial bars giving too high a bearing stress on the sides of the ridges in comparison with the shearing stress in the concrete between the ridges.

STUDIES OF BACTERIUM COLI IN PRIVATELY OWNED RURAL WATER SUPPLIES, *R. L. France* (Jour. Bact., 25 (1933), No. 6, pp. 623-635). This study, reported by the Massachusetts Experiment Station was undertaken to investigate the adequacy of the routine procedure of the standard methods of water analysis for bacteriological examination of water when applied to privately owned rural water supplies.

Two hundred and twenty-three strains of the colon-aerogenes group isolated from water, and 178 strains isolated from feces were studied. All strains were confirmed as *B. coli* by the Standard Methods procedure. When the methyl red, Voges-Proskauer, sodium citrate, and uric acid tests were employed to differentiate the strains studied into *B. coli* of fecal type and nonfecal *B. aerogenes* it was observed that a considerably greater percentage of the strains from water than of the strains from feces gave irregular results. The percentage of strains identified by the differential media as *B. coli* of fecal type was considerably greater among the strains isolated from feces than among those isolated from water. The methyl red and Voges-Proskauer tests agreed perfectly with each other for all strains tested. The sodium citrate and uric acid tests failed to agree with each other with 15 of the strains (6.7 per cent of the total) isolated from water. These tests failed to agree with each other with only one strain isolated from feces. A considerably greater number of strains isolated from water were identified as *B. coli* of fecal type by the methyl red and Voges-Proskauer tests than by the sodium citrate and uric acid tests considered separately or together.

The results obtained in this investigation suggest that dependence on the Standard Methods procedure alone for determining the sanitary quality of drinking water, especially from privately owned supplied of unknown history, results in too many of the samples being condemned. The need of supplementary differential tests is indicated, but results do not justify the recommendation of any particular test or group of tests.

SERVICE RECORDS OF TREATED AND UNTREATED POLES, *R. M. Wirka* (Elect. World, 102 (1933), No. 4, pp. 116-121, figs. 3). In a contribution from the U.S.D.A. Forest Service, data from service records of untreated and butt-treated poles are presented and analyzed. They show that the serviceable life of poles is affected by such factors as changes in wire load, reconstruction and rerouting of lines, species, soil and climatic conditions, size, and treatment, if any.

Of the butt treatments under observation the hot-and-cold bath process with creosote has been found the most effective. The brush method is less effective than the hot-and-cold bath method, but its use may sometimes be permissible where it is impracticable to use a more thorough treatment. The extension of life resulting from brush treatments with a good preservative should generally be sufficient to more than pay for the cost of application. Two coats of a good preservative applied by brushing should generally be more effective than one.

Chestnut, Northern white cedar, and Western red cedar poles that were butt treated with creosote by the hot-and-cold bath process are giving excellent service in the regions in which they are under test. Though the tops of the Western red cedar poles in southern California are being attacked by termites, they will give an average physical life of at least 25 years.

Lodgepole pine poles that were butt creosoted by the hot-and-cold bath process are giving long service in regions where top decay is not a factor, for example, in the higher altitudes of the Rocky Mountain regions. Under more severe service conditions lodgepole pine poles would need top treatment also if the maximum life is to be obtained from them.

Tests with the ponderosa pine and white fir poles that were butt treated with creosote by the hot-and-cold bath process show that in the part of California where they are being used a top treatment also is necessary for maximum service.

While the data on treatments using Anaconda Wood Preservative (dust and granules) are not very comprehensive, they indicate that this material will not be so effective as the hot-and-cold bath treatment with creosote. Increasing the resin content in pole butts proved of little value in extending the life of the lodgepole pine poles. There appears to be no advantage in seasoning poles to be used untreated before setting them in line. The extension of life to be accomplished by a thorough preservative treatment is proportionately greater in poles of nondurable species than in poles of naturally durable species. Butt treatments should extend well above the ground line if decay-producing fungi are to be repelled in that area.

EFFECT OF TETRAETHYL LEAD ON OCTANE NUMBER, *L. E. Hebl*, *T. B. Rendel*, and *F. L. Garton* (Indus. and Engin. Chem., 25 (1933), No. 2,

(Continued on page 355)

AGRICULTURAL ENGINEERING

Established 1920

A journal devoted to the advancement of the theory and practice of engineering as applied to agriculture and of the allied arts and sciences. Published monthly by the American Society of Agricultural Engineers, under the direction of the Publications Committee.

PUBLICATIONS COMMITTEE

JAMES A. KING, Chairman

H. B. WALKER R. U. BLASINGAME

W. G. KAIZER L. J. FLETCHER

The Society is not responsible for the statements and opinions contained in the papers and discussions published in this journal. They represent the views of the individuals to whom they are credited and are not binding on the Society as a whole.

Contributions of interest and value, especially on new developments in the field of agricultural engineering, are invited for publication in this journal. Its columns are open for discussions on all phases of agricultural engineering. Communications on subjects of timely interest to agricultural engineers, or comments on the contents of this journal or the activities of the Society, are also welcome.

Original articles, papers, discussions, and reports may be reprinted from this publication, provided proper credit is given.

RAYMOND OLNEY, Editor

R. A. PALMER, Associate Editor

Logical Subsidized Building

IF IT is desirable, in the interest of reemployment, for the federal government to foster and finance building projects, a most logical place for such building is on the farm. Apparently the cities have a great plenty of office, hotel, and apartment buildings. In general, the same seems to be true of industrial and commercial structures.

Slum clearance has emotional appeal and a worthy social purpose, but plans for erection of model tenements already have aroused opposition from landlords, not so much owners of the slum property to be directly displaced, but of a better class of apartments with an uncomfortably high percentage of vacancy. On the face of things it would seem wiser to shift slum populations into existing vacancies, even at reduced rentals and valuations, than to create still more vacancy with its disastrous reaction on average property earnings.

The slum dwellers on American farms are no less deserving of better quarters than the occupants of city tenements. There are no existing better homes into which farm families might be shifted. If they are to have better homes, those homes must be built on the land to which the families are anchored. There is no question of destroying the earning value of competitive properties. On the other hand, such dwellings become a part of permanently productive properties, affording abundant security and satisfying the theory of self-liquidation.

The doctrine of self-liquidation applies still more directly if such a farm building program is extended to livestock shelters and other structures. Although the breakdown of distribution and finance has created a seeming surplus of agricultural production capacity, the slack will be taken up with restoration of consumer purchasing power, and added capacity will be needed as infant industries using raw materials from the farm grow and multiply. The immediate need for new or improved farm buildings, however, is not for capacity, but for economy. Reduced wastes and increased efficiency for feed and labor are a route to farm relief with which even the most urban-minded could scarcely quarrel.

Decadence and obsolescence of existing farm buildings are too well known among the informed to need restatement here. The Structures Division of the American Society of Agricultural Engineers is alive to the needs, well organized, and well equipped to furnish plan service. For a large-scale federal program there probably are not enough skilled engineers for supervision. But so long as there are farm building engineers unemployed, or working at less than the full measure of their talent, common sense suggests a program cut to the size of the personnel available.

The same is true of appraisal and other administrative machinery. To at least some extent and in some localities the federal machinery for farm loans could be utilized. To a degree state agencies can be clothed with authority to assist in a federal program. Granted that the program might be spotty in its application, and that there are difficulties to be ironed out, any advance in any sector will help to restore activity and employment in the materials industry and the building trades. At least a few farmers will be helped toward more economic production, and a wholesome example set for all agriculture.

Engineering in Pest Control

THOSE who see symbolism in mere coincidence might well find support for their theory in the closely succeeding appearances of Dr. E. L. Nixon and Mr. R. M. Merrill in the technical meeting just held by the Power and Machinery Division of the American Society of Agricultural Engineers.

Dr. Nixon is a veteran plant pathologist. For years he has concentrated on the problem of profitable potato production in spite of the several serious potato diseases. By the time his studies in microbiology had developed into practical farm methods he had gone into the technology and economics of soil content and structure, all the details of tillage and supplementary cropping, in their reaction on the potato plant and on its enemies. So, too, with the chemistry, physics, engineering, and economics of fungicides, and the machinery and methods for their application.

By force of circumstances and native genius, Dr. Nixon has become *de facto* an agricultural engineer. In the few vivid moments of his informal address, he set forth a number of engineering developments, and also set up some distinctly engineering problems which he characterized, with modest whimsy, as being difficult for a mere botanist. On the heels of this came the initial report—naturally only a brief statement of projected activity—by Chairman Merrill for the newly created Committee on Pest Control.

Among the methods of pest control subject to engineered application are burning, spraying, dusting, heat sterilization, fumigation, and bait-poisoning. Obviously engineering may contribute much to the effectiveness and economic feasibility of such operations. Less apparent, but probably more important in the aggregate, is the modification of farm machinery and adjustment of farming methods to achieve commercially adequate control of pests in combination with or incidental to the major operations of crop production. The contribution of agricultural engineers to control of the corn borer, and of farm buildings specialists to exclusion or discouragement of sundry sorts of vermin, are pertinent examples.

A Correction

IN THE caption for the illustration that appeared on page 304 of the November 1933 AGRICULTURAL ENGINEERING, it was stated that the steel frame barn shown under construction was 240 feet long. The barn shown in the process of framing in this picture is 137 feet long, and the second barn to be built alongside it will be 103 feet long, making the two barns 240 feet.

Agricultural Engineering Digest

(Continued from page 353)

pp. 187-191, figs. 9). An empirical analysis is made of the relationship between the concentration of tetraethyl lead and the octane number of a gasoline, and a definition is developed for the lead susceptibility of any gasoline.

It is shown that the octane number of an ethylized gasoline is determined by a combination of five distinct factors whose proper relationships are incorporated in an ethyl blending chart. These are (1) the effectiveness of iso-octane at different concentrations in raising the antiknock value of iso-octane-heptane mixtures, i.e., the relative dimensions of octane numbers in different parts of the scale; (2) the effectivness of tetraethyl lead at different concentrations. (This compound is most eective in small concentrations, and, as more is added to a gasoline, its effect gradually diminishes); (3) the octane number of the base gasoline before tetraethyl lead is added; (4) the lead susceptibility of the gasoline; and (5) the number of cubic centimeters of tetraethyl lead added per gallon of gasoline.

This chart may be used for determining the lead susceptibility of a gasoline from the octane numbers of two blends containing different concentrations of tetraethyl lead. Lead susceptibility of gasolines made from various crudes and by several processes are given. It is emphasized that the equations on which the ethyl blending chart is derived are of an empirical nature and as such are open to error in certain specific cases. However, the chart has been checked on more than two hundred base gasolines of widely divergent types, and so far only one type of exception has been noted. It has been found in this connection that the lead susceptibility of a gasoline is not determined by the hydrocarbons alone, but may also be markedly affected by small amounts of impurities either found in the gasoline or formed on treatment.

THE SUPPORTING STRENGTH OF RIGID PIPE CULVERTS, *M. G. Spangler* (Iowa Engin. Expt. Sta. Bul. 112 (1933), pp. 100, figs. 56). Studies conducted in cooperation with the U.S.D.A. Bureau of Public Roads are reported.

The purpose of this research has been to determine the load factor for rigid pipe culverts when installed under various field conditions affecting the vertical reaction and the active lateral earth pressure, and subjected to vertical loads due to the covering earth, with or without loads due to surface traffic. The plan pursued was to conduct a number of experiments in which several pipe sections, selected at random from a given shipment, were tested in the laboratory with the 3-edge bearing test. A like number of similar sections were then loaded in the field by an actual embankment and the field strength determined. The ratio of these two strengths is the load factor for that set of pipe for the conditions under which they were installed in the field tests.

With the data thus secured as a basis, a rational theory for determining the load factor under all conditions of loading was developed. Working values of the load factor, determined in accordance with this theory, are proposed for a range of field conditions covering all cases likely to be encountered in practice.

It was found that the field supporting strength of rigid pipe is materially affected by the character of the bedding of the pipe. As a result of this study, four classifications of bedding conditions are proposed and defined to cover the range of conditions normally encountered in practice. From poorest to best these classifications are (1) impermissible projection bedding, (2) ordinary projection bedding, (3) first class projection bedding, and (4) concrete cradle projection bedding. The necessity for a definitely controlled field practice of bedding culvert pipe is clearly shown.

Marston's theory of loads on conduits due to earth fills, which assumes the vertical load on a conduit to be uniformly distributed over its breadth, was verified by analyses of the radial pressure on two culverts.

The conclusion that active lateral pressures about equal to those calculated by Rankine's formula may be considered to act against those portions of pipe culverts which project above the surface of the natural ground adjacent was reaffirmed. A large number of measurements of radial pressure on rigid culvert pipe were made by means of earth pressure cells of the type designed by Goldbeck and Smith. These cells were found to be of little value in making such measurements, primarily because the actual earth pressures vary widely from point to point and an impractical number of cells would be necessary to determine average pressures accurately. Stainless steel ribbons sliding between canvas surfaces were used to measure radial pressures and were found to be superior to the pressure cells. This superiority was due largely to the fact that while the cells measured pressure over a circular area of only 10 sq in, the ribbons being 48 in long and 0.5 in wide gave a measure of the average pressure on 24 sq in.

A devise for measuring the vertical settlement at any point in the interior of an embankment was developed as a part of this research and is fully described. While it was operated successfully, it seems to be susceptible to further development and refinement.

DURABILITY OF POSTS AND RESULTS OF PRESERVATIVE TREATMENT, *D. G. Carter, H. T. Barr*, and *J. B. Woods* (Arkansas Sta. Bul. 287 (1933), pp. 16, fig. 2). This bulletin reports the progress of laboratory and field studies extending over a 10-year period, from 1923 to 1933, on the life of fence posts and the use of preservative treatments for post woods. Three phases of the study are reported: (1) The durability of fence posts in service, (2) tests of preservative treatments on pine and oak specimens, and (3) the use of toxic chemicals and other preservatives in the control of wood-destroying fungi.

On the basis of 10 years of service tests, 7-year tests of wood specimens in the field, and laboratory studies of toxicity, it was found that pine posts creosoted by the pressure process were entirely sound after 10 years' service. Galvanized steel posts showed no deterioration after 10 years' service. Painted steel posts are satisfactory, but the coating is not weather resistant, and posts are subject to corrosion. Home creosote treatment of oak posts gives an apparent increase of about 4 years in length of satisfactory service. Fifty per cent of the test posts were sound after 10 years. Creosote was the most generally effective preservative in all tests.

The use of insecticides and fungicides, such as lime-sulfur spray and lubricating oil emulsion, did not prevent wood decay, although destruction was retarded somewhat when compared with untreated specimens. Used motor or cylinder oil without dilution or emulsification gave definite indications of effectiveness. Best results were secured when treatments were of short duration and at the lower temperatures. In field tests, zinc chloride treatments were found to be effective in preservation and may readily be adapted to home treatment.

Molten sulfur offered some mechanical resistance to decay. Copper compounds precipitated in the wood were found to be highly toxic to wood-destroying fungi.

This project indicates the desirability of further study on (1) the effect of length of treatment on durability, (2) the use of used motor oil as a preservative, (3) the use of chemicals in contact with the wood in the soil, (4) the value of copper compounds soluble in weak acids, and (5) treatment with and effect of zinc chloride as a preservative.

[AGRICULTURAL ENGINEERING INVESTIGATIONS AT THE MASSACHUSETTS STATION], *C. I. Gunness* (Massachusetts Sta. Bul. 293 1933), pp. 7, 8). The progress results are briefly summarized of investigations on apple storages, fertilizer distributors, and low-lift pumps.

EVAPORATION FROM SALT SOLUTIONS AND FROM OIL-COVERED WATER SURFACES, *C. Rohwer* (Jour. Agr. Res. [U.S.], 46 (1933), No. 8, pp.715-729, figs. 3). Studies conducted by the U.S.D.A. Bureau of Agricultural Engineering in cooperation with the Colorado Experiment Station are reported.

Comparisons were made of the rate of evaporation from water in standard land evaporation pans and from similar pans covered with oil or containing various concentrations of sodium chloride and sodium sulfate. A film of transformer oil or medium engine oil reduced the evaporation, but dissipation of the film by rain, wind, and other causes rendered this an uneconomical method for reducing evaporation from large surfaces. From 2, 5, 10, and 20 per cent solutions of sodium chloride the evaporation was 97, 98, 93, and 78 per cent, respectively, of that from water. From 2, 5, and 10 per cent solutions of sodium sulfate the evaporation was 104, 98, and 98 per cent, respectively, of that from water. Evaporation from the salt solutions followed the same law as evaporation from water, correction being made in the computations for the effect of the salt upon the vapor pressure.

POWER AND MACHINERY IN AGRICULTURE, *W. M. Hurst* and *L. M. Church* (U. S. Dept. Agr., Misc. Pub. 157 (1933), pp. 39, figs. 17). This publication summarizes data from various sources on the changes effected by power and machinery, kinds of power and its geographic distribution, amount and cost of power, and major developments in farm tractors.

The data show that nearly 17,000,000,000 hph are developed annually on farms in the United States, and that animals furnish approximately 50 per cent of this power. A simple method of approximating the duty of a tractor or horse-drawn implement is expressed by the equation

$$D = \frac{SW\ 5{,}280\ (100-P)10}{43{,}560 \times 100}$$

in which D is duty in acres per day, S speed in miles per hour, W effective width in feet, 5,280 number of feet per mile, P per cent of time lost in turning and in servicing, 10 number of hours worked per day, and 43,560 number of square feet per acre.

An appendix presents statistics relating to tractors, horses and mules, and certain farm conveniences.

A NEW TYPE OF INSTALLATION FOR MEASURING SOIL AND WATER LOSSES FROM CONTROL PLATS, *H. V. Geib* (Jour. Amer. Soc. Agron., 25 (1933), No. 7, pp. 429-440, figs. 11). In a contribution from the U. S. D. A. Bureau of Chemistry and Soils a detailed description is given of a type of devisor box which was found to work very satisfactorily, along with a description of the complete installation as it is now being used on the soil erosion and moisture conservation control plats at the Blackland Erosion Experiment Station at Temple, Tex.

A type of divisor box was evolved which gave practically the same aliquot at all stages of flow. The outlet of weir end of this box consisted of a number of identical rectangular slots, stamped out with a die to insure greater accuracy and uniformity. This multislot divisor box was found to be very accurate and entirely suitable for use alone or in series to obtain a definite aliquot of the run-off from erosion control plats.

DOMESTIC USES OF GAS, *A. E. Forstall* et al (Scranton, Pa.: Internatl. Textbook Co., [1932], pp. IV+[150], figs. 55). This is a technical handbook on domestic uses of gas and the design and installation of equipment. It deals with gas lighting, water heaters, cooking appliances, space heaters, gas piping and flues, refrigeration, domestic clothes driers and incinerators, distribution and use of gas, transmission of gas, distribution of natural gas, comparison with manufactured gas, distribution precautions with natural gas, distribution mains, making joints in mains, metering gas to consumers, reading of gas meters, installing and testing meters, house piping, and utilization of natural gas.

SEPTIC TANKS AND PRIVIES [trans. title], *I. Coulpier* (Jour. Agr. Prat., 97 (1933), No. 19, pp. 381-384, figs. 4). Brief practical information is given on the construction of sanitary privies and septic tank sewage disposal systems for country use in France.

FUEL OILS; COMMERCIAL STANDARD CS12-33 (Washington: U. S. Bur. Standards, 1933, 2. ed., pp. II+13, fig. 1). The text of specifications covering six grades of fuel oil for various types of fuel-oil-burning equipment is presented.

WHAT ELECTRICITY COSTS IN THE HOME AND ON THE FARM, edited by *M. L. Cooke* (New York: New Republic, 1933, pp. XXI+231+[43], pls. 2, figs. 3). This is a symposium on the cost of distribution of electricity to domestic and rural consumers consisting of papers presented before the Institute of Public Engineering in New York City, January 20, 1933. Among these were papers on The Physical Characteristics of the Distribution Plant, by W. E. Herring (pp. 6-12); The General Problem of Cost-Allocation, by J. M. Clark (pp. 13-23); The Development of Industrial Cost Keeping, by N. M. Perris (pp. 24-36); Service Elements and Costs of Distributing Electricity to Retail Customers, by H. W. Reed (pp. 37-52); Distribution Cost of Electric Energy with Special Reference to Residence and Rural Customer, by C. W. Pike (pp. 75-102); The Relation of Local Costs to System Costs in the Production and Distribution of Electric Energy, by R. Husselman (pp. 118-144); On the Variations in Distribution Costs per Customer as

(Continued on page 360)

A.S.A.E. and Related Activities

A.S.A.E. Section Meetings

DURING the earlier part of the new year two and possibly three meetings of geographical sections of the American Society of Agricultural Engineers will be held to record the progress of agricultural engineering development during the past year in the respective sections of the country embraced by these sections, to encourage greater cooperation between individual agricultural engineers, and to coordinate the activities of individuals and groups in rendering a larger measure of service in the field of engineering as applied to agriculture.

As announced in the November AGRICULTURAL ENGINEERING, the meeting of the North Atlantic Section of the Society usually held in October will be held at Harrisburg, Pennsylvania, January 17 to 19, which dates coincide with the annual Pennsylvania Farm Show.

While the final technical program for the meeting is not at this writing available, it will cover the general features referred to in the November AGRICULTURAL ENGINEERING. The meeting will open with a session on Wednesday afternoon, January 17. The evening of that day will be devoted to a number of round table discussions arranged to be of particular interest to those who attend the meeting. Two sessions, forenoon and afternoon, will be held the following day, and the yearly dinner of the section is scheduled for the evening of that day.

The forenoon session for Friday, January 19, will officially close the meeting, and arrangements are being made for the group to visit the Pennsylvania Farm Show during the afternoon of that day.

The sessions will be held at the downtown Y.M.C.A., at North and Front Streets, and inasmuch as there are a great many visitors in Harrisburg during the Farm Show, those attending this meeting are urged to make room reservations early. The rates at the Y.M.C.A. for non-members of that organization range from $1.25 to $1.75 per person. Reservations should be made direct with Mr. J. M. McKee, 707 Telegraph Building, Harrisburg, Pa.

Reduced fares (1½ fare per trip) will be effective for persons residing in New York, New Jersey, Delaware, Maryland, Virginia, and West Virginia. Those attending the meeting from the states named should write Mr. McKee for a reduced fare certificate, which they can present when purchasing their ticket to the meeting.

The principal meeting of the Pacific Coast Section is usually held in January. A meeting of the Section was held at Pamona, California, on November 3. At this writing an announcement of a meeting in January has not been received, but on account of the unusual activity in various branches of the federal service, and with which a large percentage of Pacific Coast members of the Society are associated, there appears some doubt that a January meeting will be held.

For several years the Southern Section of the Society has held its meeting at the same time and place as the annual meeting of the Association of Southern Agricultural Workers. This meeting is usually held the first week in February, and while an announcement of the program has not yet been received, it is assumed that the usual Section meeting will be held. As in the case of the Pacific Coast Section, however, federal government projects are keeping A.S.A.E. members in this section unusually busy, and it is therefore difficult for them to attend meetings.

About ASAE Members

G. M. Foulkrod, formerly associated with the agricultural engineering staff at Pennsylvania State College, on September 1, joined the new agricultural engineering department that has been organized at the University of New Hampshire, at the head of which is *W. T. Ackerman*. Mr. Foulkrod's major activity will be that of college instruction in agricultural engineering.

Henry Giese, agricultural engineer, Iowa Agricultural Experiment Station, is author of Bulletin No. 303, entitled "Thermal Conductivity and Surface Treatment of Silo Walls," recently issued by that station.

E. J. McKibben and *M. A. Sharp*, agricultural engineers, Iowa State College, are listed as two of the authors of Extension Service Bulletin No. 192, entitled "Adjustment and Repair of Mowers," recently issued by that institution.

R. L. Patty and *L. W. Minium*, agricultural engineers, South Dakota Agricultural Experiment Station, are authors of bulletin No. 277, entitled "Rammed Earth Walls for Farm Buildings," recently issued by that institution.

J. R. Tavernetti, associate in agricultural engineering, California Agricultural Experiment Station, is author of Circular No. 329, entitled "Construction and Operation of Mechanical Refrigerators for Farms," recently issued by that institution.

New ASAE Members

Frederick A. Brooks, associate agricultural engineer, University of California Agricultural Experiment Station, University Farm, Davis, Calif. (Mail) Box 293.

Julian L. Schueler, chief metallurgist, Continental Steel Corporation, Kokomo, Ind.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the November issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Alfons Alven, Chicago manager, Bearings Company of America, Engineering Building, 205 W. Wacker Drive, Chicago, Ill.

E. M. Dieffenbach, assistant mechanical engineer, Division of Mechanical Equipment, Bureau of Agricultural Engineering, U. S. Department of Agriculture. (Mail) P. O. Box 429, Albany, Georgia.

Benjamin R. Ellis, trade extension manager, Southern Cypress Manufacturers Association, Barnett Bank Building, Jacksonville, Florida.

Melville Monroe Johns, agricultural engineer, Virginia Electric and Power Company, Richmond, Virginia.

Ray Clifford Noll, secretary, treasurer, chief engineer, and general manager, Whiterock Quarries, Bellefonte, Pa. (Mail) Pleasant Gap, Pa.

Clarence Bentley Richey, ratesetter, David Bradley Manufacturing Works, Bradley, Ill. (Mail) 491 S. Dearborn Ave., Kankakee, Ill.

Transfer of Grade

Clesson Turner, agricultural engineering specialist, extension service, University of Maine, Orono, Maine. (Mail) 22 Myrtle St. (Jr. to Assoc. Mem.)

G

n,
n-
or
y

i-
g-
is
d
e-
"
n.

g-
of
nt
s,

r-
n,

D
or
ri-
a-
AL
re
ts
c-

r,
n-
er

e-
e-
of
e-
l)

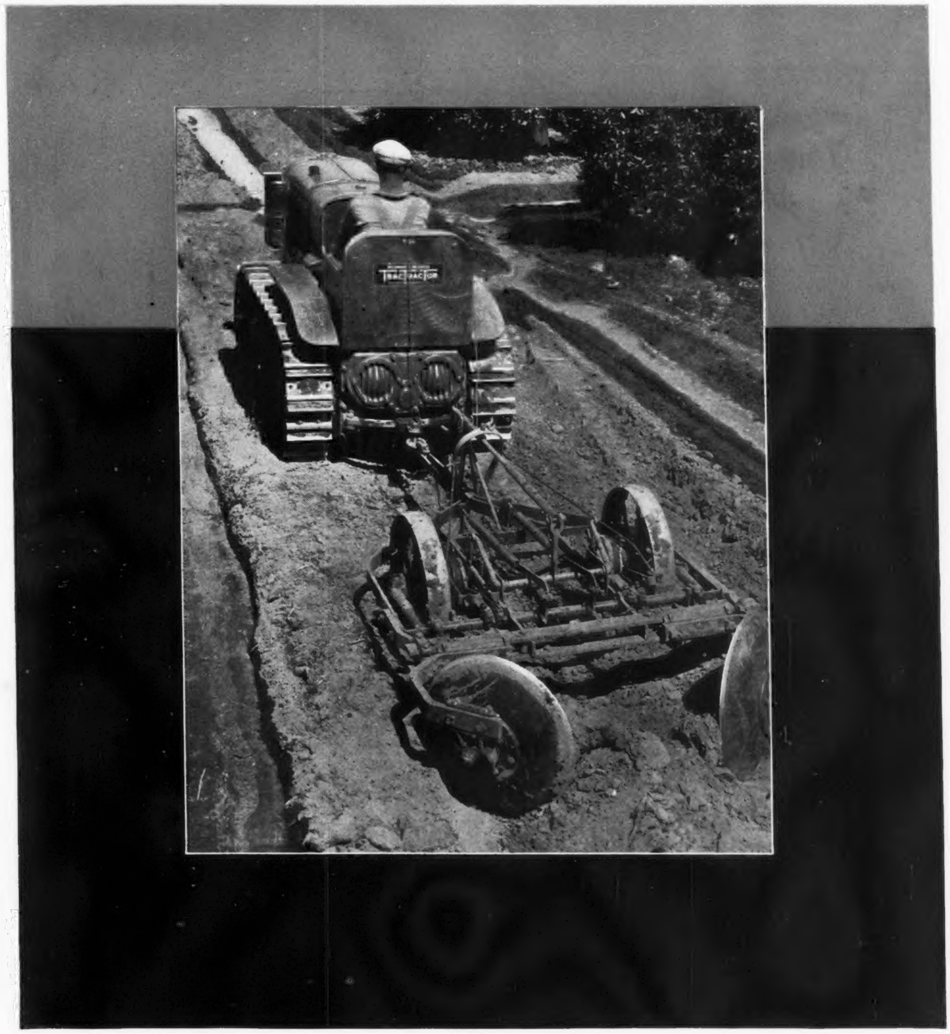
on
u-
nk

l-
ic
d,

y,
n-
es,
p,

e-
ng
S.

gi-
er-
o,
to



to
en
er
es

he
en
ne
d-
re-
lls
er
is

hy
nt
ry.

IIO

S